THE AMERICAN ENCYCLOPEDIA AND DICTIONARY OF OPHTHALMOLOGY

EDITED BY

CASEY A. WOOD, M. D., C. M., D. C. L.

Professor of Ophthalmology and Head of the Department, College of Medicine, University of Illinois; Late Professor of Ophthalmology and Head of the Department, Northwestern University Medical School; Ex-President of the American Academy of Medicine, of the American Academy of Ophthalmology, and of the Chicago Ophthalmological Society; Ex-Chairman of the Ophthalmic Section of the American Medical Association; Editor of a "System of Ophthalmic Therapeutics" and a "System of Ophthalmic Operations"; Mitglied der Ophthalmologischen Gesellschaft, etc.; Ophthalmic Surgeon to St. Luke's Hospital; Consulting Ophthalmologist to Cook County Hospital, Chicago, Ill.

ASSISTED BY A LARGE STAFF OF COLLABORATORS

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INITIALS USED IN THIS ENCYCLOPEDIA TO IDENTIFY INDIVIDUAL CONTRIBUTORS

A. A.—ADOLF ALT, M. D., M. C. P. AND S. O., ST. LOUIS, MO.
Clinical Professor of Ophthalmology, Washington University, St. Louis, Mo.; Author of *Lectures on The Human Eye; Treatise on Ophthalmology for the General Practitioner; Original Contributions Concerning the Glandular Structures Appertaining to the Human Eye and its Appendages.* Editor of the *American Journal of Ophthalmology.*

A. C. C.—ALFRED C. CROFTAN, PH. D., M. D., CHICAGO, ILL.
Author of *Clinical Urinology* and of *Clinical Therapeutics.* Member of the General Staff of the Michael Reese Hospital, Chicago. Formerly Physician-in-chief at St. Mary's Hospital; Physician to St. Elizabeth's Hospital; Physician to the Chicago Post-Graduate Hospital; Pathologist to St. Luke's Hospital. Late Professor of Medicine at the Chicago Post-Graduate College and the Chicago Polyclinic; Assistant Professor of Clinical Medicine, College of Physicians and Surgeons (University of Illinois); Member of the American Therapeutic Society.

A. E. B.—ALBERT EUGENE BULSON, JR., B. S., M. D., FORT WAYNE, IND.
Professor of Ophthalmology, Indiana University School of Medicine; Chairman of the Section on Ophthalmology of the American Medical Association; Ophthalmologist to St. Joseph's Hospital, Allen County Orphans' Home, and the United States Pension Department; Editor of the *Journal of the Indiana State Medical Association,* etc.

A. E. H.—ALBERT E. HALSTEAD, M. D., CHICAGO, ILL.
Professor of Clinical Surgery, Northwestern University Medical School; Attending Surgeon, St. Luke's and Cook County Hospitals, Chicago; Consulting Surgeon, Illinois Charitable Eye and Ear Infirmary; Fellow American Surgical Association.

A. N. M.—ALFRED NICHOLAS MURRAY, M. D., CHICAGO, ILL.
Ophthalmologist, New Lake View Hospital. Formerly Clinical Assistant in Ophthalmology, and Assistant Secretary of the Faculty, Rush Medical College. Once Voluntary Assistant in the Universitaets Augenklinik, Breslau. Author of *Minor Ophthalmic and Aural Technique.* Secretary, Physicians' Club of Chicago. Mitglied der Ophthalmologischen Gesellschaft, Heidelberg.

A. S. R.—ALEXANDER SANDS ROCHESTER, M. D., CHICAGO, ILL.
M. D. Jefferson Medical College; Ex-Chief, San Lazaro Contagious Hospital, Manila, P. I.; Adjunct Ophthalmologist to St. Luke's Hospital, Chicago.

B. C.—BURTON CHANCE, M. D., PHILADELPHIA, PA.
Assistant Surgeon, Wills Hospital, Philadelphia.

C. A. O.—CHARLES A. OLIVER (DECEASED).

C. D. C.—CARL DUDLEY CAMP, M. D., ANN ARBOR, MICH.
Clinical Professor of Diseases of the Nervous System in the Medical Department of the University of Michigan. Formerly, Instructor in Neuropathology in the University of Pennsylvania. Member of the American Neurological Association, American Association of Pathologists and Bacteriologists, American Therapeutic Society, American Medical Association, etc. Author of papers on the Anatomy, Physiology and Pathology of the Nervous System.

C. E. W.—LIEUT.-COL. CHARLES E. WOODRUFF, M. D., U. S. ARMY, RETIRED.

C. F. F. C.—CHARLES F. F. CAMPBELL, COLUMBUS, OHIO.
Superintendent Ohio State School for the Blind; Secretary Ohio State Commission for the Blind; Secretary, American Association of Workers for the Blind; Founder and Editor, "*Outlook for the Blind;*" Previously executive officer of the Massachusetts Association for Promoting the Interests of the Blind, Massachusetts State Commission for the Blind, and Pennsylvania Association for the Blind; At one time Teacher at the Royal Normal College and Academy of Music, for the Blind, London, England.

C. F. P.—CHARLES F. PRENTICE, M. E., NEW YORK CITY, N. Y.
President, New York State Board of Examiners in Optometry; Special Lecturer on Theoretic Optometry, Columbia University, New York. Author of *A Treatise on Ophthalmic Lenses* (1886); *Dioptric Formulæ for Combined Cylindrical Lenses* (1888); *A Metric System of Numbering and Measuring Prisms (the Prism-dioptry)* (1890); *The Iris as Diaphragm and Photostat* (1895), and other optical papers.

C. H. B.—CHARLES HEADY BEARD, M. D. (DECEASED).

C. P. S.—CHARLES P. SMALL, A. M., M. D., CHICAGO, ILL.
Late Clinical Assistant, Department of Ophthalmology, Rush Medical College. Author of *A Probable Metastatic Hypernephroma of the Choroid.*

D. C. MC.—DOUGLAS C. MCMURTRIE, NEW YORK CITY.
Editor *American Journal of Care for Cripples;* former Secretary, American Association for the Conservation of Vision; Author of *Education of and Occupations for the Blind* in the *Reference Handbook of the Medical Sciences.*

D. H.—D'ORSAY HECHT, M. D. (DECEASED).

D. W. G.—DUFF WARREN GREENE, M. A., M. S., M. D. (DECEASED).

E. C. B.—EDWARD C. BULL, PASADENA, CALIF.

E. C. E.—EDWARD COLEMAN ELLETT, B. A., M. D., MEMPHIS, TENN.
Professor of Ophthalmology, University of Tennessee, College of Medicine.

E. E. I.—ERNEST E. IRONS, M. D., PH. D., CHICAGO, ILL.
Assistant Professor of Medicine, Rush Medical College; Assistant Attending Physician, Presbyterian Hospital; Attending Physician, Cook County Hospital; Consulting Physician, Durand Hospital of the Memorial Institute for Infectious Diseases, Chicago.

E. H.—EMORY HILL, A. B., M. D., CHICAGO, ILL.
Late House Surgeon, Wills Eye Hospital, Philadelphia; Assistant in Ophthalmology, Rush Medical College (in affiliation with the University of Chicago); Assistant Ophthalmologist to the out-patient department of the Children's Memorial Hospital, Chicago; Assistant Instructor in Ophthalmology, Chicago Polyclinic. Member of American Academy of Ophthalmology and Oto-Laryngology.

E. J.—EDWARD JACKSON, C. E., M. A., M. D., DENVER, COLO.
Professor of Ophthalmology in the University of Colorado; Former Chairman of the Section on Ophthalmology of the American Medical Association; Former President of the American Academy of Ophthalmology and Oto-Laryngology; The American Ophthalmological Society, and The American Academy of Medicine. Author of *Skiascopy and its Practical Application; Manual of Diseases of the Eye;* Editor of *Ophthalmic Year-Book* (nine volumes); *Ophthalmic Review; Ophthalmic Record;* and *Ophthalmic Literature*

E. K. F.—Ephraim Kirkpatrick Findlay, M. D., C. M., Chicago, Ill.
Assistant Clinical Professor of Ophthalmology, Medical Department, University of Illinois; Assistant Surgeon of the Illinois Charitable Eye and Ear Infirmary; Assistant Oculist at the University Hospital.

E. S. T.—Edgar Steiner Thomson, M. D., New York City, N. Y.
Surgeon and Pathologist, Manhattan Eye, Ear and Throat Hospital; Professor of Ophthalmology, New York Polyclinic Medical School and Hospital; Consulting Ophthalmologist to Perth Amboy and Ossining Hospitals; Member of the New York Academy of Medicine, New York Ophthalmological, and American Ophthalmological Societies. Author of *Electric Appliances and Their Use in Ophthalmic Surgery,* in Wood's *System of Ophthalmic Operations,* and various monographs.

F. A.—Frank Allport, M. D., LL. D., Chicago, Ill.
Ex-Professor, Ophthalmology and Otology, Minnesota State University; Ex-President, Minnesota State Medical Society; Ex-Chairman and Secretary, Ophthalmic Section, American Medical Association; Ex-Professor, Ophthalmology and Otology, Northwestern University Medical School; Ex-President, Chicago Ophthalmological Society. Author of *The Eye and Its Care;* Co-Author of *An American Text-Book of Diseases of the Eye, Ear, Nose and Throat; A System of Ophthalmic Therapeutics,* and *A System of Ophthalmic Operations.* Eye and Ear Surgeon to the Chicago Board of Education and to St. Luke's Hospital, Chicago.

F. C. T.—Frank C. Todd, D. D. S., M. D., F. A. C. S., Minneapolis, Minn.
Professor of Ophthalmology and Chief of the Division of Eye, Ear, Nose and Throat, University of Minnesota, Medical Department; Chief of Eye, Ear, Nose and Throat Staff, University of Minnesota Hospitals; Eye, Ear, Nose and Throat Surgeon to Hill Crest Hospital; Eye Surgeon to the C. M. & St. P. R. R. Co., etc.; Chairman of the Section of Ophthalmology, A. M. A.; President of the Minnesota Academy of Ophthalmology and Oto-Laryngology; Vice-President of the A. M. A., etc. Monographs: *An Exact and Secure Tucking Operation for Advancing an Ocular Muscle; A Method of Performing Tenotomy which Enables the Operator to Limit the Effect as Required; Mules' Operation; Keratectasia; Report of a Case with Transparent Cornea; The Implantation of an Artificial Vitreous as a Substitute for Enucleation of the Eyeball; Simple Method of Suturing the Tendons in Enucleation; Malingering (Pretended Blindness); The Physiological and Pathological Pupil.*

F. E. B.—Frank E. Brawley, Ph. G., M. D., Chicago, Ill.
Co-Author of *Commoner Diseases of the Eye, A System of Ophthalmic Therapeutics* and *A System of Ophthalmic Operations;* formerly voluntary assistant in the Universitaets Augenklinik, Breslau, and the Royal London Ophthalmic Hospital (Moorfields); Oculist and Aurist to St. Luke's Hospital, Chicago. Editorial Secretary of *The Ophthalmic Record.*

F. P. L.—Francis Park Lewis, M. D., Buffalo, N. Y.
President American Association for the Conservation of Vision; President Board of Trustees N. Y. State School for the Blind; President N. Y. State Commissions for the Blind (1903 and 1906); Chairman Committee on Prevention of Blindness, American Medical Association; Ophthalmologist Buffalo State Hospital and Buffalo Homeopathic Hospital; Consulting Ophthalmologist J. N. Adam Memorial Hospital; Fellow Academy Ophthalmology and Oto-Laryngology.

G. C. C.—See *G. C. S.*

G. C. S.—G. C. Savage, M. D., Nashville, Tenn.
Professor of Ophthalmology in the Medical Department of Vanderbilt University; Ex-President of the Nashville Academy of Medicine; Ex-President of

the Tennessee State Medical Society. Author of *New Truths in Ophthalmology* and *Ophthalmic Myology.*

G. F. L.—GEORGE FRANKLIN LIBBY, M. D., OPH. D., DENVER, COLORADO.

Ex-Assistant Surgeon to the Maine Eye and Ear Infirmary; Ophthalmologist to National Jewish Hospital for Consumptives, Mercy Hospital, and Children's Hospital, Denver; and Denver, Laramie and North Western Railroad; Member of the American Ophthalmological Society, Academy of Ophthalmology and Oto-Laryngology, and Colorado Ophthalmological Society (its Secretary for six years); Author of *Monocular Blindness of Fifty Years' Duration: Restoration of Vision Following Hemiplegia; Polyps in the Lower Canaliculus; Silver Salts in Ocular Therapeutics; Ocular Disease in Relation to Nasal Obstruction and Empyema of the Accessory Sinuses (Bibl.); A Case of Complete Albinism: Observations on the Changes in the Diameters of the Lens as Seen through the Iris; Consanguinity in Relation to Ocular Disease; Heredity in Relation to the Eye (doctorate thesis, Univ. of Colo., 1913); Acquired Symmetrical Opacities of the Cornea of Unusual Type; Tuberculosis of the Bulbar Conjunctiva,* etc.

H. B. C.—H. BECKLES CHANDLER, C. M., M. D., BOSTON, MASS.

Professor Ophthalmology, Tufts Medical School, Boston; Senior Surgeon Massachusetts Charitable Eye and Ear Infirmary.

H. B. W.—HENRY BALDWIN WARD, A. B., A. M., PH. D., CHAMPAIGN, ILL.

Professor of Zoology, University of Illinois; Ex-Dean of the College of Medicine, University of Nebraska. Author of *Parasitic Worms of Man and the Domestic Animals; Data for the Determination of Human Entozoa; Iconographia Parasitorum Hominis; Human Parasites in North America.*

H. F. H.—HOWARD F. HANSELL, A. M., M. D., PHILADELPHIA, PA.

Professor of Ophthalmology, Jefferson Medical College; Emeritus Professor Diseases of the Eye, Philadelphia Polyclinic Hospital; Ophthalmologist to Jefferson Medical College Hospital; Ophthalmologist to Philadelphia Hospital.

H. G. L.—HENRY GLOVER LANGWORTHY, M. D., DUBUQUE, IOWA.

Surgeon to the Langworthy Eye, Ear, Nose and Throat Infirmary, Dubuque, Iowa; Member American Academy of Ophthalmology and Oto-Laryngology; of the Chicago Ophthalmological Society; of the American Medical Association, etc. Writer of numerous monographs on the special subjects of eye, ear, nose and throat.

H. S. G.—HARRY SEARLS GRADLE, A. B., M. D., CHICAGO, ILL.

Professor of Ophthalmology, Chicago Eye and Ear College; Director of Ophthalmic Clinic, West Side Free Dispensary; Member of the Ophthalmologische Gesellschaft, American Medical Association, American Academy of Ophthalmology and Oto-Laryngology.

H. V. W.—HARRY VANDERBILT WÜRDEMANN, M. D., SEATTLE, WASH.

Managing Editor, *Ophthalmology,* since 1904; Editorial Staff of the *Ophthalmic Record* since 1897; Managing Editor, *Annals of Ophthalmology,* 1897-1904. Member American Medical Association; Ex-Chairman Section on Ophthalmology, American Medical Association; Hon. Member, Sociedad Cientifica, Mexico; N. W. Wisconsin Medical Society and Philosophical Society. Fellow American Academy of Ophthalmology and Oto-Laryngology. Author of *Visual Economics* (1901); *Injuries to the Eye* (1912); *Bright's Disease and the Eye* (1912); and numerous monographs on the eye and its diseases. Collaborator on many other scientific books.

J. D. L.—JOSEPH D. LEWIS, A. M., M. D., MINNEAPOLIS, MINN.

Ophthalmic and Aural Surgeon to the Minneapolis City Hospital; Consulting Ophthalmic and Aural Surgeon to Hopewell Hospital and Visiting Nurses' Association; Member Minnesota Academy of Ophthalmology and Oto-Laryngology; Fellow American College of Surgeons.

J. G., Jr.—John Green, Jr., A. B., M. D., St. Louis, Mo.
Assistant in Ophthalmology, Washington University Medical School; Ophthalmic Surgeon to St. Louis Children's Hospital; Ophthalmic Surgeon to St. Louis Eye, Ear, Nose and Throat Infirmary; Consulting Ophthalmic Surgeon to St. Louis Maternity Hospital; Consulting Ophthalmic Surgeon to St. John's Hospital, St. Louis.

J. L. M.—John L. Moffat (Deceased).

J. M. B.—James Moores Ball, M. D., LL. D., St. Louis, Mo.
Dean and Professor of Ophthalmology, American Medical College of St. Louis, Medical Department of National University of Arts and Sciences. Author of *Modern Ophthalmology; Andreas Vesalius the Reformer of Anatomy.*

J. R. C.—James Raley Cravath, B. S., Chicago, Ill.
Electrical and Illuminating Engineer, Chicago; Vice-President, Illuminating Engineering Society; formerly associate editor *Electrical World;* joint author *Practical Illumination* by Cravath and Lansingh; joint author *Light—Its Use and Misuse,* prepared by committee of the Illuminating Engineering Society; author of *Illumination and Vision; Tests of the Lighting of a Small Room;* and numerous other monographs.

L. H.—Lucien Howe, M. A., M. D., Sc. D., Buffalo, N. Y.
Professor of Ophthalmology, University of Buffalo; Member of the Royal College of Surgeons of England; Fellow of the Royal Society of Medicine; Member of the *Ophthalmologische Gesellschaft* and of the *Société Française d'Ophthalmologie.* Author of *The Muscles of the Eye.*

L. M.—Lloyd Mills, M. D., Los Angeles, Cal.
Late Voluntary Assistant II Eye and I Surgical Services *(Abteilung Budinger)* Vienna General Hospital.

M. S.—Myles Standish, A. M., M. D., S. D., Boston, Mass.
Williams Professor of Ophthalmology, Harvard University; Consulting Ophthalmic Surgeon, Massachusetts Charitable Eye and Ear Infirmary and Carney Hospital, Boston, Mass.

N. M. B.—Nelson M. Black, Ph. G., M. D., Milwaukee, Wis.
Author of *The Development of the Fusion Center in the Treatment of Strabismus; Examination of the Eyes of Transportation Employes; Artificial Illumination a Factor in Ocular Discomfort,* and other scientific papers.

P. A. C.—Peter A. Callan, M. D., New York City, N. Y.
Surgeon, New York Eye and Ear Infirmary; Ophthalmologist to St. Vincent's Hospital; Columbus Hospital and St. Joseph's Hospital, New York.

P. G.—Paul Guilford, M. D., Chicago, Ill.
Ex-Resident Surgeon, Wills Eye Hospital, Philadelphia; Attending Oculist and Aurist, St. Luke's Hospital; Attending Oculist and Aurist, Chicago Orphan Asylum; Consulting Oculist and Aurist, South Side Free Dispensary. Co-Author of *A System of Ophthalmic Operations.*

R. D. P.—Robert D. Pettet, Chicago, Ill.
Author of *The Mechanics of Fitting Glasses.*

S. H. McK.—Samuel Hanford McKee, B. A., M. D., Montreal, Que.
Lecturer in Pathology and Bacteriology, McGill University; Demonstrator in Ophthalmology, McGill University; Assistant Oculist and Aurist to the Montreal General Hospital; Oculist to the Montreal Maternity Hospital; Oculist to

the Alexandra Hospital; Member of The American Association of Pathologists and Bacteriologists. Author of *The Bacteriology of Conjunctivitis; An Analysis of Three Hundred Cases of Morax-Axenfeld Conjunctivitis; Demonstration of the Spirocheta Pallida from a Mucous Patch of the Conjunctiva; The Pathological Histology of Trachoma,* and numerous other monographs.

T. A. W.—THOMAS A. WOODRUFF, M. D., C. M., L. R. C. P.

Ex-President of Chicago Ophthalmological Society; Vice-President of the Illinois Society for the Prevention of Blindness; Fellow of A. M. A.; Fellow American Academy of Medicine; Fellow of American Academy of Ophthalmology; Formerly Editorial Secretary of the *Ophthalmic Record;* Fellow American College of Surgeons; Fellow of the Institute of Medicine of Chicago; Member of Chicago Society of Medical History; Chicago Medical Society; Author with Casey A. Wood of *Commoner Diseases of the Eye;* Formerly Ophthalmic Surgeon to St. Luke's Hospital.

T. H. S.—THOMAS HALL SHASTID, A. B., A. M., M. D., LL. B., F. A. C. S., SUPERIOR, WIS.

Honorary Professor of the History of Medicine in the American Medical College, St. Louis, Mo.; Late Editorial Secretary of *The Ophthalmic Record,* Author of *A Country Doctor; Practising in Pike; Forensic Relations of Ophthalmic Surgery* (in Wood's *System of Ophthalmic Operations); Legal Relations of Ophthalmology* (in Ball's *Modern Ophthalmology); A History of Medical Jurisprudence in America* (in Kelly's *Cyclopedia of American Medical Biography).*

W. C. P.—WM. CAMPBELL POSEY, B. A., M. D., PHILADELPHIA, PA.

Professor of Ophthalmology in the Philadelphia Polyclinic Hospital and Graduate Medical School; Ophthalmic Surgeon to the Wills, Howard and Children's Hospitals; Chairman of the Pennsylvania Commission for the Conservation of Vision; Chairman of Section on Ophthalmology, College of Physicians, Philadelphia. Editor of American Edition of Nettleship's *Textbook of Ophthalmology;* Co-Editor, with Jonathan Wright, of *System of Diseases of the Eye, Ear, Nose and Throat;* Co-Editor, with Wm. G. Spiller, of *The Eye and the Nervous System.*

W. F. C.—W. FRANKLIN COLEMAN (DECEASED).

W. F. H.—WILLIAM FREDERIC HARDY, M. D., ST. LOUIS, MO.

Assistant in Ophthalmology, Washington University Medical School.

W. H. W.—WILLIAM HAMLIN WILDER, A. M., M. D., CHICAGO, ILL.

Professor and Head of Department of Ophthalmology, Rush Medical College (in affiliation with University of Chicago); Professor of Ophthalmology, Chicago Polyclinic; Surgeon, Illinois Charitable Eye and Ear Infirmary; Ophthalmic Surgeon, Presbyterian Hospital; Member American Ophthalmological Society.

W. O. N.—WILLIS ORVILLE NANCE, M. D., CHICAGO, ILL.

Ophthalmic Surgeon, Illinois Charitable Eye and Ear Infirmary; Late Oculist and Aurist to Cook County Hospital; President, Chicago Ophthalmological Society.

W. R.—WENDELL REBER (DECEASED).

W. R. P.—WALTER ROBERT PARKER, B. S., M. D., DETROIT, MICHIGAN.

Professor of Ophthalmology, University of Michigan; Attending Ophthalmic Surgeon, University Hospital, Ann Arbor; Children's Hospital, Detroit; Consulting Ophthalmologist, Woman's Hospital, Detroit; Ex-Chairman Ophthalmic Section American Medical Association; Associate Editor *Annals of Ophthalmology;* Member of the American Ophthalmological Society; Fellow of the American College of Surgeons.

Convex lenses helpful. Errors of refraction that complicate an esophoria should be measured under a mydriatic, and a full correction should be given. If the error is hyperopia, every dioptre of correction will relieve 1.8°, practically 2°, of the esophoria both in the far and in the near; if the error is hyperopic astigmatism, every dioptre of correction will relieve 0.9°, practically 1°, of the esophoria. The pseudo-esophoria is thus cured. Any remaining esophoria is intrinsic in character, unless it be caused by subnormally developed ciliary muscles, which would be shown in the near only.

Concave lenses hurtful. If the refractive error is myopia, every dioptre of correction will add to the manifest esophoria—in the near, but not in the far—1.8°, that quantity of pseudo-exophoria which, before correction, served to lessen the esophoria; if the error be myopic astigmatism, every dioptre of correction would add 0.9° to the formerly manifest esophoria, but in the near only. With the correcting lenses on, the esophoria shown by the phorometer is intrinsic in character.

Thus it is shown that the correction of hyperopia and hyperopic astigmatism lessens the nervous tension of the externi by relieving the associated nervous tension of both the interni and the externi; while in intrinsic esophoria the nervous tension is in the externi alone, the tension of the interni being inherent. To obtain full correction of the pseudo-esophoria, the hyperopia and the hyperopic astigmatism should be fully corrected, and the correction must be worn both for near and for far seeing. If the esophoria is wholly pseudo, nothing will be needed but the lenses for effecting a complete cure; but if a part of the esophoria is intrinsic, as may always be known without waiting, other treatment will be necessary sooner or later. The double nervous tension having been relieved by the lenses, all symptoms may vanish for a time; but ultimately the nervous tension of the externi, necessary for correcting the intrinsic esophoria, will cause symptoms to reappear. This marked relief will follow only when the intrinsic esophoria is low in degree, while the pseudo-esophoria is comparatively high.

The wearing of lenses correcting myopia and myopic astigmatism will cause no change in the muscle imbalance for distance; but in the near, the wearing of the lenses will cause the whole of the esophoria to become manifest, and the nervous tension of the externi will be correspondingly augmented; the symptoms will be aggravated, and the esophoria should receive immediate treatment. Until the esophoria has been cured it will be better to let the patient take the lenses off

when engaging in near work, or, at most, wear only a partial correction of the myopic error. Uncorrected myopia lessens the nervous tension of the externi in esophoria by diminishing the normal nervous impulse that would be sent to the interni, if the ciliary muscles were in full action.

The effect of focal errors eliminated, the treatment of the intrinsic esophoria depends on the quantity of the error, in so far as non-operative efforts are concerned.

The non-operative treatment of esophoria of low degree is of two kinds—first, prisms in position of action for the stronger muscles or of rest for the weaker muscles; second, exercise of the weaker muscles, which, in cases of esophoria, can be accomplished only by prisms.

Prisms in positions of action for the interni. Prisms to be worn constantly are always open to the objection that they interfere with the law of direction, but this is sometimes the less of two evils and should be chosen. The visual axis under any and all circumstances points to the apparent source of the light that throws its image on the macula. In obedience to the law of corresponding retinal points, an image that has been displaced, by prismatic action, toward the temporal side of the macula, makes the source of the light appear to be on the opposite side and just as many degrees from its real position as the image has been displaced from the macula. When possible, fusion of the false object with the true object is effected by the internus rotating the eye until the macula is brought under the displaced image. The visual axis points to where the object would appear to be, if no attempt at fusion had been made, and of necessity passes through the center of retinal curvature. The visual line that passes from the displaced image to the fused object passes to the outer side of the center of the retinal curve, and is a false line of direction.

Before placing a prism for constant wear by an esophoric, the complicating muscle errors must be considered. The only indication for placing the axis of the prism out of the horizontal is the coexistence of cyclophoria, usually a plus cyclophoria, either with or without a complicating hyperphoria of the one eye and a cataphoria of the other. If there is no vertical error, but only a plus cyclophoria complicating the esophoria, the prismatic effect should be divided equally between the two eyes, and the nasal end of each axis should be tilted up through a sufficient arc for correcting the greater part of the cyclophoria through contraction of the superior recti. This must be determined by testing for the cyclophoria while the prisms are on. The stronger the prisms, the smaller the arc of rotation of the axes; and, vice versa, the weaker the prisms, the larger the arc of rotation. To place

the prisms in such a case, with the axes horizontal, would be to leave uncorrected the cyclophoria, a most important factor in the causation of symptoms. To depress the nasal end of the axes of the prisms, in a case of this kind, would be to make the patient worse through contraction of the inferior recti.

If there is a complicating hyperphoria of one eye and cataphoria of the other eye, as well as a complicating plus cyclophoria, the prismatic effect for the relief of the esophoria should be applied wholly or in greater part to the eye that is hyperphoric and the nasal end of the axis should be elevated. As can be readily seen, a prism thus placed would cause the eye to turn in and up, the direction the strong muscles tend to take it, which rotation would tort the eye in, correcting the plus cyclophoria. If any of the prismatic effect is applied to the cataphoric eye, the axis should be horizontal, for the reason that, while depressing the axis of the prism would rest the weak superior rectus, it would increase the plus cyclophoria; on the other hand, elevating the nasal end of the axis would favor the weak superior oblique, but would add to the abnormal nervous tension of the weak superior rectus.

In a case of esophoria, complicated with a minus cyclophoria, the rule for tilting the axes of the prisms would be reversed all the way through. This complication is exceedingly rare.

If the esophoria is uncomplicated in a given case, the prismatic effect should be equally divided between the two eyes. These prisms can be worn with comfort, provided the two interni are properly attached, and in many cases they can be worn comfortably if the two interni are attached, in greater part, above the horizontal plane of the eyes. In many cases the superior obliques would accept kindly the aid, in paralleling the vertical axes with the median plane of the head, offered by the interni that are attached too high. Constant prisms for esophoria, when uncomfortable, point to attachments of the interni that are, in greater part, below the horizontal plane. In such a case the prisms would have to be abandoned. The combined prismatic effect, as a rule, should not be more than half the esophoria.

Decentered lenses. When focal errors require either convex or concave lenses, these can be decentered so as to give the necessary prismatic effect. For esophoria, convex lenses should be decentered out and concave lenses should be decentered in. The same rules for placing prisms should govern the decentering of lenses. It would seem that authors ought to agree as to how much a given lens should be decentered in order to obtain a definite prismatic effect, but they do not. Maddox teaches that a lens of 1 D. must be decentered at 1.75

cm. (17 5mm.) to obtain 1° of prismatic effect. He then gives the following formula for determining the extent of decentration of any lens for a required effect: $C = \frac{P \times 1\frac{3}{4}}{D}$, in which C is the centimeters of decentering; P, the desired prismatic effect; and D, the number of dioptres in the lens. Let $P = 1\frac{1}{2}°$ and $D = 3$, then the formula would be: $C = \frac{1\frac{1}{2} \times 1\frac{3}{4}}{3} = .875$ cm., or 8.75 mm., which is about ⅓ of an inch of decentering.

Jackson teaches that the following formula is practically correct: $C = \frac{P \times 10}{D}$, in which C is the mm. of decentering required; P, the prismatic effect desired; D, the number of dioptres in the lens to be decentered; while 10 is the mm. of decentering of a 1 D. lens for 1° (1 centrad) of effect. Substituting figures for letters, as in the Maddox formula, we have: $C = \frac{1\frac{1}{2} \times 10}{3} = 5$ mm., or about 1/5 of an inch of decentering, as compared with Maddox's ⅓ of an inch of decentering.

Thorington and May agree in taking 8.7 mm. for the extent of decentering a 1 D. lens in order to procure 1° of prismatic effect. For obtaining the amount of decentration of any lens, this would be their formula: $C = \frac{P \times 8.7}{D}$. Substituting figures for letters, as in the other formulas, we have: $C = \frac{1\frac{1}{2} \times 8.7}{3} = 4.35$ mm., or about 1/6 of an inch of decentration, as compared with Maddox's ⅓ of an inch and Jackson's 1/5 of an inch; or, comparing in mm.: Maddox, 8.7; Jackson, 5; Thorington, 4.35; May, 4.35. By a little experimentation the reader may satisfy himself that Jackson is practically correct. The extent of decentration advised by Maddox is entirely too much—nearly double what it ought to be. It may be that Maddox's estimate was for 1° of arc, and not for 1° of prism, or 1 centrad.

One advantage that decentering a lens has, over the grinding of a lens on a prism, is that the former is cheaper; another advantage is that the wearing of a decentered lens is not attended by the re-

flected image of any bright object, which is always toward the refracting angle and in the line of the axis of the prism, unless the prism is ground on both surfaces. Chromatic aberration is no more, nor is it any less, with a decentered lens than it is with a lens ground on a prism. The great objection to decentered lenses is that the spherical aberration must interfere to some extent with the sharpness of retinal images; this, however, is but little when the decentering is 6 mm. or less, and rarely is it more. In very strong lenses, say 6 D., the decentering would be only 5 mm. for 6° of effect.

The greatest objection to "relieving prisms" and to decentered lenses is that they favor muscles in their weakness. They lessen nervous tension, but not by increasing the inherent power of weak muscles. It is far better practice to increase the inherent power of weak muscles, either by exercising them or by shortening or advancing them; or to increase the relative power of the weaker muscles by lessening the tension of their stronger antagonists by partial tenotomies. If patients will not resort to exercise, and decline to submit to operations, they should be given the benefit which is to be derived from prisms in positions of rest or from decentered lenses.

Exercise treatment for esophoria. Uncomplicated intrinsic esophoria of low degree may be cured by proper exercise of the externi. The only means applicable are prisms. The same gymnastic principles apply to the externi as to the other muscles of the body. Light work, not continued too long, and rhythmic in character, is exercise that increases muscular power. Prisms of from 1° to 4°, bases in, can be used for developing the externi. Beginning with the weaker prisms and advancing to the next stronger at intervals of a week or ten days, the strongest to be used are soon reached. The exercise should be resorted to at the same time every day, so as to easily form the habit of exercising, and should be continued not longer than ten minutes at a time. One exercise daily—or, at most, two exercises daily—will be sufficient. Lenses correcting focal errors should be worn at the time of exercising. The exercise prisms in spectacle frames should be lowered and raised alternately every three seconds throughout the sitting. The object looked at may be anything that can be seen distinctly and it should be distant from the observer not more than twenty feet nor less than ten feet. Looking at the object through the prisms, the externi are made to contract; raising the prisms, these muscles at once relax. Thus contraction and relaxation, rhythmic in character, are continued throughout the sitting. Exercise that fatigues does not build, hence the necessity of always stopping short of fatigue. A muscle develops as the result of exercise in proportion to the

abundance of blood that can be brought into it. Abundance of blood supply means quick results; scanty blood supply, because of smallness of the vessels entering the muscle, means slow results. These conditions cannot be known beforehand; therefore it is better to tell the patient that the treatment will have to be continued for months.

Exercise of the externi that are attached, in greater part, below the horizontal plane, will exercise, at the same time, the inferior obliques, which would be good in a case of minus cyclophoria, but bad in one of plus cyclophoria. If the externi have the ideal attachment—that is, half above and half below the transverse plane of the eye—exercise will always be well borne and will do good. If attached too high, the exercise of the externi will be associated with exercise of the superior obliques and will usually be well borne and ought to do good. These things can be known only as a result of exercise.

The object in view in exercising the externi is to so increase their inherent power that, under a normal impulse, they will be able to do a normal amount of work; that their tension may be inherent, not nervous, and sufficient to balance the inherent tension of the interni.

Operations. No operation for pseudo-esophoria should ever be done. The kind depending on hyperopia should be treated by a full correction of the focal error; the kind due to subnormal development of the ciliary muscles, making it necessary that the center controlling them shall generate an extraordinary nerve impulse, should be treated by gymnastic exercise of these muscles, as set forth in the earlier part of this study.

Safe operative line. There can be drawn no unvarying line between operative and non-operative cases of intrinsic esophoria. If, under the red-glass test, there is homonymous diplopia, the case is almost certainly one to be operated upon; but the kind of operation is not shown by this test. If the esophoria at 16 inches is more than half the angle of convergence (nearly 9°) for that distance, the question of operation should be considered; and if it is much in excess of 5° in the near, there is no reason why an operation should be delayed. Whatever the quantity of esophoria in the distance, which is usually a little greater than that in the near, it should not be relied on exclusively when determining on an operation. Both the near and the far tests should always be noted. The quantity of error being sufficiently great to indicate an operation, the next thing to consider is the question as to whether the esophoria is sthenic or asthenic. More than 25° of adduction and more than 50° of adversion would indicate a partial tenotomy of one or both interni; there is nothing in esophoria that can justify a complete tenotomy. If the adduction is 25° or less

and the adversion is 50° or less, no operation should be done on the interni, but one or both externi should be shortened. If in doubt as to which of the two operations should be done, it would be safer to choose the shortening of an externus. Either operation would cure wholly, or in part, the imbalance—the partial tenotomy, by lessening the tonicity of the internus; the shortening, by increasing the tonicity of the externus. In properly selected cases either operation would establish a sthenic orthophoria; in unfortunately selected cases (those with normal or subnormal adduction) the tenotomy would establish an asthenic orthophoria, a danger never attending the operation of shortening.

Abduction in an operable case of esophoria is a safe guide in determining whether the operation should be done to lessen the tonicity of an internus or to increase the tonicity of an externus. If the abduction is above 5° or 6° and the abversion is but little below 50°, the internus should be cut; if abduction is below 5° and abversion is correspondingly low, the externus should be shortened.

In uncomplicated cases of esophoria, the error about equal in the two eyes, the operative effect should be divided between them. In such cases the plane of rotation must not be altered, hence the partial tenotomy must be central and the shortening must be straight-forward.

When esophoria is complicated with only hyperphoria of one eye and cataphoria of the other, the operations on the lateral muscles should be done as if there were no complications—that is, the tonicity of the muscles should be altered, but their planes should not be changed. Later the hyperphoria should be treated either by a permanent prism for the hyperphoric eye, by prismatic exercise of the weaker muscle of each eye, or by a central partial tenotomy of the superior rectus of the hyperphoric eye.

When esophoria is complicated by cyclophoria alone or by cyclophoria and hyperphoria, the operation done must not only alter the tonicity of the muscle, but must also change its plane of rotation. If the complication is plus cyclophoria alone and the operation is to lessen the tonicity of the internus, it should be so done as to elevate its plane of rotation. This is accomplished by a lower marginal tenotomy. leaving uncut the fibers at the upper margin. A threefold effect attends this operation: (a) the tension is lessened, (b) the cyclophoria is counteracted, (c) a hyperphoria is created. For the reason that an operation on only one internus would give a hyperphoria to the corresponding eye, the operative effect should be divided between the two eyes, the operation on the one internus being as nearly as possible like the operation on the other. The two operations should cure the

esophoria and the plus cyclophoria; but at the same time a double hyperphoria would be created, a condition far less objectionable than the two errors for the cure of which the operations were done.

If the sthenic esophoria is complicated by plus cyclophoria, with hyperphoria and cataphoria, the operative effect should be confined, if possible, to the internus of the cataphoric eye and should consist of a division of the lower and central fibers, leaving uncut enough of the upper fibers to prevent an over-effect. The result of this operation would be threefold: (a) lessening or curing the esophoria; (b) counteracting the plus cyclophoria; (c) converting the cataphoria into a hyperphoria, thus giving the patient a double hyperphoria. If some of the esophoria should remain, it should be relieved by a central partial tenotomy of the internus of the other eye. A marginal tenotomy of this muscle should not be done, even if some of the plus cyclophoria and hyperphoria remained, for the reason that dividing its lower fibers would increase the hyperphoria while curing the cyclophoria. How to deal with any remaining cyclophoria and hyperphoria will be shown in the discussion of those conditions.

If the esophoria is asthenic and uncomplicated, one of the externi, if not both, should be shortened so as to increase its tonicity without changing its plane of action. If complicated by a hyperphoria of one eye and a cataphoria of the other, there being no cyclophoria, the shortening of the externi should be done as if no complication existed; that is, the tonicity should be increased, but the plane should not be changed. If complicated by a plus cyclophoria only, both externi should be shortened to the same extent and the plane of each should be lowered sufficiently to effect a correction of the cyclophoria. The alteration of the tonicity would cure the esophoria. If the complications are plus cyclophoria and a hyperphoria of one eye and a cataphoria of the other, the operative effect, if possible, should be limited to the hyperphoric eye, and should be accomplished by a shortening of the externus so as both to alter its tonicity and to depress its plane of action. The triple effect would be: (a) increased tonicity for the esophoria; (b) lowered plane for the plus cyclophoria; (c) lowered plane for the hyperphoria, converting it into a cataphoria, so that there would be a double cataphoria. If any remaining esophoria should require a shortening of the externus of the other eye, the operation should be done so as to increase its tonicity without changing its plane, even if there should also remain, from the first operation, some of the plus cyclophoria and some of the cataphoria; for a change of the plane of action that would lessen one of these complications would increase the other.

The complication of minus cyclophoria has only been mentioned, for the reason that it is so rare. When it does exist in connection with esophoria, every step for changing the muscle plane, as set forth in the treatment of a plus cyclophoria, must be reversed.

The operation of shortening an externus, when enough increase of tonicity can be had, should always be preferred to an advancement. While this can be done in nearly all cases of asthenic esophoria, in which an increase of tonicity of the externi is always indicated, nevertheless, in some cases these muscles have their attachment so far removed from the corneo-scleral junction that the advancement operation becomes clearly indicated. The same rules, as to alteration of tonicity and change of plane, apply to advancements as have been set forth in connection with shortenings. For the technic of these operations, and the after-treatment, the reader is referred to the section on operations on the ocular muscles (following).

While doing these operations the judgment of the operator must decide as to their extent. His judgment cannot be good unless he keeps in mind the exact nature of the conditions for the relief of which he is operating. The true essence of these conditions cannot be known except as a result of the most skillful and careful use of the phorometer, cyclophorometer, and tropometer or perimeter. Before any operation is done, the refraction of the eyes should be determined, under a mydriatic, by means of the standard objective and subjective tests. The operator should always be careful not to do too much; for it is far better to leave the patient with some of his esophoria than it is to give him the smallest quantity of the opposite error—exophoria. The danger of resorting to tests while operating is that it may lead to the doing of too much. Tests while operating cannot be reliable, and should, therefore, be avoided. When more than one operation is needed, it is better to allow from two to four weeks to intervene; but in errors of high degree, two operations, a partial tenotomy of an internus and a shortening of the opposing externus, or a partial tenotomy of both interni, or a shortening of both externi, may be done at the same time.

The object of partial tenotomies of the interni, in the treatment of esophoria, is to so reduce their tonicity that the externi, under a normal impulse, may perfectly balance them in action. The object of shortening the externi is to so increase their inherent tonicity that, under a normal impulse, they may perfectly balance the interni. In either case the nervous tension of the externi would be relieved.

Whenever an intrinsic esophoria has been reduced by operations so that the remainder can be cured by non-operative means, these

should be resorted to, but not until the muscles operated upon have had time to completely recover from the operations. The treatment of esophoria, by whatever means, relieves in part, or wholly, the right and left fourth basal or fusion centers from activity in the interest of binocular single vision. The main purpose of all muscle operations is to make the two muscles of a pair equal in tonicity—orthophoric.

EXOPHORIA.

As the word indicates, there is, in exophoria, a tendency on the part of the external recti muscles and their synergists to make the visual axes deviate from the point of fixation. If this tendency were not counteracted by antagonists of the externi, the visual axes would either intersect beyond the point of fixation, or they would become parallel or even divergent. Abnormal nervous tension of the interni and their synergists counteracts the inherent tonicity of the externi and their synergists, so that the tendency is not allowed to become a turning. The visual axes are thus forced to intersect at the point of fixation; and binocular single vision is maintained, but at the expenditure of an undue amount of nerve force. Exophoria, like esophoria, is of two kinds, intrinsic and pseudo. As to causation, the one kind is wholly different from the other, but the two often coexist. As to the results, the one is the same in kind as the other, but the treatment of the one is not at all similar to the treatment of the other.

Intrinsic exophoria. In this the externi have the advantage over the interni. This imbalance may be due to the fact that the externi are hyper-developed, or that the interni are of subnormal development. It may be that the error is not in the size of the muscles, but in the nature of their attachment to the globe, the externi having their attachment nearer the corneo-scleral junction than normal, or that the interni are attached too far back; it may be that the externi are short and tense or that the interni are long and somewhat lax. When either of these conditions causes exophoria, the error may be greater in the one eye than in the other, though, as a rule, the exophoria is about equal in the two eyes. When there is a difference, the monocular phorometer quickly shows it.

An intrinsic exophoria can exist without there being a state of real imbalance between the externi and the interni. The oblique muscles are always more or less powerful as abvertors. There is but little room for doubt that, in some cases, they may be too short and tense, or they may be too large and powerful, or their attachments may be nearer the posterior pole than normal, so that, in either case, their

abverting power would be increased. This increase may be sufficiently great to cause an exophoria, even when there is no cyclophoria.

Malformation of the orbits, only in the sense of their being too far apart, can cause an exophoria; but when this cause exists alone, the muscle imbalance cannot be great.

The superior and inferior recti may have their attachments so far toward the temples as to greatly lessen their power to help the interni, and thus become a factor in the production of exophoria.

Whether the one or the other of the several conditions named is the cause of exophoria, or whether two or more of them become factors in the production of this error, the treatment, whether surgical or non-surgical, must be directed toward the lateral muscles. As to surgical means, either the tonicity of the externi must be lessened or the tonicity of the interni must be increased. If brain-centers are structurally over-developed or under-developed, they must remain so always; if the obliques, because of structure, attachment, or innervation, abvert too powerfully, they cannot be changed; if the orbits are too wide apart, surgery cannot bring them closer together. If the superior and inferior recti, because of faulty attachments, are feeble advertors, they must not be subjected to operations on this account. For these reasons it becomes apparent that any and every treatment of intrinsic exophoria, whatever may be the cause, must be directed toward the externi or toward the interni. An exophoria that is wholly muscular, all innervation centers being normal, will show the same number of degrees in the near as in the far.

Intrinsic exophoria is of two kinds, sthenic and asthenic. The quantity of the error does not determine its character. Only the abduction and the abversion tests, in any given case, can tell the operator that the error is sthenic or that it is asthenic. Exophoria with abduction of less than 8° and abversion of less than 50° is asthenic, and clearly indicates that the externi should not have their tonicity lessened, and just as clearly indicates that the interni must have their tonicity increased. Exophoria with abduction of more than 8° and abversion of more than 50° is sthenic, and the case should be treated with the view of lessening the tension of the externi.

Tests in myopic and emmetropic cases will always show the full amount of intrinsic exophoria in the far. In the near test of a myope, the intrinsic exophoria will have the associated pseudo-exophoria added to it. If the emmetrope does not show the same exophoria in the near as in the far, it is increased or diminished because of an abnormal development of the ciliary muscles. If the ciliary muscles are hyper-developed, there will be more exophoria in the near than in

the far, for the reason that an impulse less powerful than normal is required of the brain-center controlling them, so that a correspondingly slight associated impulse is sent to the interni. If the ciliary muscles are subnormally developed, they will require an impulse more powerful than the normal, and a correspondingly strong associated impulse must be sent to the interni, causing a pseudo-esophoria, which, to a certain extent, would neutralize the intrinsic exophoria.

Pseudo-exophoria. There can be but two causes for this condition. One is myopia, or myopic astigmatism; the other is hyper-development of the ciliary muscles, making it necessary for the centers controlling them to generate a less powerful nerve current than would be required by these muscles if normally developed.

When the cause is myopia, or myopic astigmatism, the pseudo-exophoria shows itself only in the near, and is due to the fact that the guiding sensation calls either for no nerve force to excite ciliary action or for a quantity less than is required by an emmetrope, depending on the amount of the focal error; and a correspondingly slight associated impulse is sent to the interni. If the point of view is 16 inches distant, there should be 1.8° of pseudo-exophoria for each dioptre of myopia up to 2.50 D. and .9° for each dioptre of myopic astigmatism up to 5 D. This kind of pseudo-exophoria does one of three things: (a) it increases an intrinsic exophoria in the near, (b) it shows an exophoria in the near when there is real orthophoria, or (c) it lessens an intrinsic esophoria in the near.

When the pseudo-exophoria is due to a hyper-development of the ciliary muscles and the patient is an emmetrope, the error will show itself only in the near test. If a 1.50 D. impulse is all that is necessary to effect a 3 D. contraction of the ciliary muscles, the pseudo-exophoria, with the test object at 13 inches, shoud be 2.7°. This may manifest itself in the same three ways as that caused by myopia. Strictly speaking, a pseudo-exophoria cannot exist in a hyperope; although, as shown in the section on esophoria, the hyperope who has hyper-developed ciliary muscles will show a less amount of pseudo-esophoria than would be shown if these muscles were of normal development. The difference in amount is equivalent to pseudo-exophoria.

When the far test shows orthophoria and the near test shows exophoria, the error is pseudo in character, and is dependent on one or other of the two causes above mentioned; and the same is true when an exophoria is less in the far than it is in the near. The same explanation applies when there is esophoria in the far and exophoria in the near. If, in an emmetrope, there is more exophoria in the far than there is in the near, the ciliary muscles are subnormally developed,

and require an excessive impulse to make them perform their work. The associated impulse to the interni is correspondingly great.

There is a form of exophoria not yet referred to in this section, and probably not fully set forth in any book. The cause unquestionably resides in the third conjugate innervation center, and is structural in character; in other words, the third conjugate innervation center is subnormally developed, and, for this reason, sends a feeble impulse to the interni. The most exaggerated manifestation of this condition would lead one to judge that this brain-center is entirely absent, for occasionally a case is seen having no power of convergence. Such a person enjoys binocular vision in the distance, but has only monocular vision in the near. In such a case there is no convergence power, for the one visual axis cannot be made to approach the other. Abversion will be normal or even above the normal. Adversion is unimpaired, showing that the fourth and fifth innervations have full sway. The abversion of the right eye equals the adversion of the left eye, and, vice versa, the abversion of the left eye equals the adversion of the right eye. In these movements the visual axes are kept parallel, as when the eyes are looking straight ahead. That the condition is congenital in most cases is shown by the fact that there is no diplopia in the near. This must be due to an acquired mental suppression of images that fall on the temporal half of the retina, or, at least, a portion of it. The power of mental suppression can be acquired only in the earliest years of life.

If the third innervation center can be entirely absent in one person and be present and fully developed in another, it is reasonable to conclude that in still another it may be present, but in a state of subnormal development. There may be as many different grades of development of this as there are individuals; but in the majority of persons this center is able, doubtless, to generate 1° of impulse for every 1° of convergence, in association with the center of the ciliary muscles.

Subnormal development of this center must manifest itself in an exophoria in the near many degrees in excess of the exophoria in the far (of itself it can never cause exophoria in the far, but it may be associated with some of those conditions that cause intrinsic exophoria); or, if there is orthophoria or even slight esophoria in the far, there will be considerable exophoria in the near. The two ordinary causes of pseudo-exophoria—that is, myopia and hyper-developed ciliary muscles—will not cause more than 5° of the error. A greater degree of variation between the far and the near tests than this, in the exophoric direction, must be attributed to a subnormally devel-

oped third conjugate brain-center. A diagnostic feature of this condition is the manifestation of very low abduction power—much lower than is found in intrinsic exophoria of the same degree.

Tests. The cover test, allowing the eye to turn toward the temple, will be attended by a resetting of the eye toward the nose when the cover is removed, and the false object will move rapidly toward the corresponding side until fused with the true object. The examiner can often see the resetting of the eye, but not so readily as an intelligent patient can detect the apparent movement of the test object.

Red-glass test. The red glass, in the higher grades of exophoria, will develop crossed diplopia. The distance between the red light and the true light will give a fair idea of the quantity of the error. This test, resulting in crossed diplopia, practically always indicates operative treatment; but since it does not show whether the case is sthenic or asthenic, it cannot indicate the character of the operation to be done.

Double-prism test. The double prism held before the right eye so that the two lights seen through it shall be in the same vertical line, the light seen by the left eye will be to the right, if there is exophoria. The extent of the error is shown by that prism, base toward the nose, that will place the middle light in line with the other two. This test, so far as it goes, is safe and accurate; but it cannot show whether the exophoria is sthenic or asthenic, and cannot, therefore, be relied upon in answering the question: "What operation, if any, shall be done?"

Single-prism test. The single six-degree prism, held base up before the right eye, with the axis perfectly vertical, is as reliable as the double prism, though one can never be so certain that the axis is vertical as he can be when using the double prism. The lower, or false, light will be on the opposite side—crossed diplopia. The prism, base in, that brings it directly under the true candle, measures the amount of the exophoria. Like the double-prism test, this one does not show whether the exophoria is sthenic or asthenic.

Maddox rod test. The rod test is less reliable in exophoria than in esophoria, for the reason that images displaced in the temporal part of the retinal fusion area seem to excite a greater demand for fusion than when displaced in the nasal part. Nevertheless, if the exophoria is sufficiently great, the rod held with its axis horizontal before the right eye will cause the streak of light to appear to the left of the candle. The prism, base in, that brings this vertical streak into the candle, measures, but not with accuracy, the exophoria. It always shows less exophoria than really exists. Maddox thinks that a red rod

makes this test practically perfect, if, at the same time, a plain green or blue glass be held before the other eye.

Monocular phorometer test. The safe, sure, speedy, and easy test for exophoria is by means of the phorometer, and of all the phorometers the monocular is the most reliable in its results. The method of testing for exophoria is the same as that for esophoria, the position of the false object always determining whether it is the one or the other error. It is always on the opposite side in exophoria. The error is measured by revolving the rotary prism until the false object is brought under the true object, when the index will mark the quantity of the error. In the same way the other eye should be tested. In the phorometer test, as in all others, the exophoria at 16 inches should also be determined.

Duction test. The next step is the taking of the abduction. This is the chief means for determining whether the exophoria is sthenic or asthenic. Unless the character of the error is known, it is not possible to resort to rational treatment. Whatever means may have been used in detecting the imbalance, the lifting power of the externi—abduction—must be taken.

This can be done, but not quickly nor accurately, by holding prism after prism, base in, before one eye, until the patient can no longer fuse the images. The chief objection to this method is the uncertainty about the axis of this prism being perfectly horizontal. The rotary prism of the phorometer, the instrument being perfectly leveled, is the quickest and best means for determining abduction or any other kind of duction. To test abduction with the rotary prism, the handle must be horizontal and the index must start from zero. Moving the index toward the temple it must be stopped the moment the patient says the test object becomes double. The index stands opposite the number indicating the degree of abduction. If this is less than 8°, the exophoria is asthenic; if more than 8°, it is sthenic. If abduction is just 8°, since it would indicate that the tonicity of the externus should not be lessened, the exophoria should be classed as asthenic, from an operative standpoint.

Abversion. Lastly, abversion should be taken either with the perimeter or the tropometer. This will usually be found less than 50°, if abduction is low, and more than 50°, if abduction is high.

While abduction and abversion are to be relied on most, adduction and adversion should always be taken. In fact, the study of no muscle error is complete until all other errors have either been found or eliminated; and the individual strength of every muscle must be known. It is only in this way that the real nature of an exophoria

can be known, and without this knowledge, rational treatment is impossible.

Complications of exophoria. These are the same as found in connection with the study of esophoria. They need only be mentioned here, as, under the head "Treatment," it will be shown how they modify the management of the exophoria. They are: myopia and myopic astigmatism, hyperopia and hyperopic astigmatism, hyperphoria and cataphoria, and plus and minus cyclophoria. Thus it appears that not only the relationship of every pair of muscles, and the condition of every individual muscle, must be known, but the refraction must also be understood, if one would deal successfully with exophoria.

Symptoms. The subjective symptoms—or, more correctly speaking, the reflex nervous symptoms—caused by exophoria are those outlined under the head "Symptoms of heterophoria." The symptoms, whatever they may be, are not due to the inherent tonicity of the externi and their synergists, but to the nervous tension of the interni and their synergists, necessary for maintaining binocular singular vision. A symptom of which exophories very commonly complain is a blurring or running together of the letters of the printed page, after more or less prolonged reading. At such times the reader feels compelled to close the eyes tightly before resuming his reading. Another symptom, often present when near work is being done, is a heavy, sleepy feeling of the upper lids, also a stiff feeling of the upper lids, as if they were adherent to the globes. Prolonged near work congests the margins of the lids, even developing a marginal blepharitis, more commonly in exophoria than in any other form of heterophoria. A drawing sensation on the nasal side of the eyes is often complained of. There is no facial expression or pose of the head that is peculiar either to exophoria or to esophoria.

Treatment of exophoria. Non-operative. In pseudo-exophoria the cause should always be removed, if practicable, by non-operative means. The pseudo-exophoria caused by myopia and found only in the near, when it serves to neutralize a part of an inherent esophoria, should be allowed to continue until the esophoria has been cured by prisms in positions of rest, by exercise of the externi, or by operations. By the non-treatment of a pseudo-exophoria of this character is meant that the myopic correction should not be worn in near work. For distant seeing the myopic correction should always be worn, for it neither adds to, nor diminishes, any form of heterophoria. If a myope is orthophoric for distance, the concave lenses should be worn for all purposes. With the lenses on for distant seeing there will still be

orthophoria; with them on in near work the pseudo-exophoria is relieved and the patient becomes orthophoric in the near as well. If the myope is exophoric in the distance, the concave lenses should be worn for all purposes. The distant test will show the same exophoria with and without the lenses. In the near test without the lenses, the exophoria shown will be the intrinsic plus the pseudo; and with the lenses will be only the intrinsic, the pseudo-exophoria having been cured by the establishment of the normal relationship between the center of convergence and the center of ciliary action.

The pseudo-exophoria caused by over-development of the ciliary muscles, requiring less than a 1 D. impulse to effect a 1 D. contraction of these muscles, is best treated by the wearing of concave lenses, only in the near, if the patient is an emmetrope, but both in the far and in the near if the patient is slightly hyperopic. By so doing a pseudo-esophoria is developed which lessens the exophoria. If the diagnosis is correct—that is, if the exophoria is wholly or in part pseudo—the wearing of concave lenses will be attended by a source of relief. When they cause discomfort, they should be discarded; for the exophoria is due to some other cause than hyper-development of the ciliary muscles.

It will be remembered by many that J. J. Chisolm, of Baltimore, was in the habit, for many years, of prescribing concave cylinders when his patients had hyperopic astigmatism. Although he did not so teach, nevertheless his patients that were benefited had exophoria. An esophoric patient would not have tolerated such lenses.

Patients who are hyperopic and have either pseudo or inherent exophoria should never be given the full correction of the hyperopia, for the imbalance would be made worse. If the hyperopia is less than 2 dioptres and the exophoria in the near is more than 4°, no correction should be given; if more than 2 dioptres, only the excess should be corrected. After an exophoria has been cured by exercise or by operation, a full correction of the hyperopia may be given, but in most cases 0.50 D. should go uncorrected.

What has been said of myopic and hyperopic corrections, in cases of exophoria, applies proportionately to astigmatic (myopic or hyperopic) corrections. How to deal with these errors when there is a complicating esophoria has already been emphasized.

Those unfortunate subjects who have no converging power, probably because of absence of the third conjugate innervation center, cannot be relieved by either lenses, prisms, exercise, or operations.

Rest prisms. The treatment of the two forms of inherent exophoria is the same, so far as concerns non-operative means. The first of these is prisms in positions of rest (bases in) for the weak interni. The

full correction of exophoria by prisms should not be attempted; probably only a half correction of the error should be given. Maddox suggests a correction of half or a third of the distant and a quarter of the near exophoria. When there is no complicating cyclophoria, the prismatic effect should be equally divided between the two eyes, and the axes of the prisms should be perfectly horizontal. The same rule holds good when there is a hyperphoria of one eye and a cataphoria of the other. If there is a complicating plus cyclophoria without any hyperphoria, the prismatic effect should be equally divided between the two eyes; but the axis of each should be tilted down at the temporal end, so as to make the externi tort the eyes in, while turning them out, to fuse the displaced images. The axes should be tilted in the opposite direction if the complication is a minus cyclophoria. When the complication is a plus cyclophoria with a right hyperphoria and a left cataphoria, the exophoric prism should be placed only before the hyperphoric eye and its axis should be tilted down at the temporal end. The muscular action necessary for overcoming the prism will turn the eye out and down and tort it in. If discomfort results, it will be due to the work that the inferior rectus has had to do to overcome the prismatic displacement. If any prism is placed before the left (cataphoric) eye, its axis should be perfectly horizontal, for, if tilted down at the temporal end, it would favor the cyclophoria, but increase the cataphoria; while, if tilted up, it would force a correction of the cataphoria, but would increase the plus cyclophoria. If there is doubt as to whether the axes of the exophoric prisms should be tilted, it is better to place them exactly horizontal. Weak exophoric prisms, with their axes perfectly horizontal, should bring some relief to most patients. When they do not relieve, it thus becomes evident that one externus, if not both, is attached too high, and there is developed a plus cyclophoria.

The objection raised against esophoric rest-prisms, that they interfere with the law of direction, applies with equal force to prisms in positions of rest for exophoria.

Decentration of lenses, in for convex and out for concave, will accomplish the same results for exophoria as will prisms with bases in. The rules for decentration have already been given.

Exercise treatment. Candle exercise. There are two useful methods of exercising the weak interni in cases of exophoria. The simplest, if not the best, and certainly the cheapest, is the candle exercise. The candle is mentioned for the reason that the images of its blaze stimulate the two retinas so as to make it more certain that the center of convergence will be excited sufficiently to converge the

visual axes, as the candle is brought from arm's length to a point six or seven inches from the eyes. Images less bright, such as those of a pencil, in some cases would not sufficiently stimulate. The exercise with the taper (small wax candle) must be conducted as follows: The patient is directed to light the taper and hold it at arm's length from, and on a plane with, the eyes, immediately in front of the face. Fixing his vision on the flame, he continues to look at it while he brings it slowly to within seven inches of his eyes, holding it there about two seconds. He then closes his eyes for a moment (at the same time moving the candle to one side) and, on opening them, fixes his vision on some distant object. The same procedure is gone through with a second time, and so on for five to fifteen times at one sitting. The sittings may be repeated one or more times daily for weeks or months. The best time for this exercise is before retiring. In many cases the evening sitting will be sufficient for the day. This is especially so, if the exophoria is low in degree.

In this taper exercise no one can doubt that the guiding sensation compels the internal recti to contract, in obedience to the law of corresponding retinal points, as the light advances, the maximum of contraction being reached when the taper is seven inches from the eyes. On closing the eyes partial relaxation of the interni occurs (keeping the eyes closed long enough, the relaxation would become complete). The moment the eyes are opened and the vision is fixed on a distant object, in quick response to the guiding sensation, the relaxation becomes complete. Thus is brought about contraction and relaxation, which should be discontinued short of fatigue. That this rhythmic exercise, properly regulated as to frequency and force, will develop the internal recti, is susceptible of demonstration on the part of any one who wishes to know the truth.

Prism exercise. The second method for developing the interni is by means of prisms, bases out. The prisms to be used may be from 1° to 8°, and one should be placed before each eye. The treatment should be commenced with the weaker prisms, and as development of the muscles advances, the stronger should be brought into use. The object looked at should be a candle, lamp, or gas jet, fifteen to twenty feet distant. With the prisms before the eyes, the image in each eye is displaced out, when the guiding sensation calls quickly into action the interni for fusing them. After three seconds the interni must be allowed to relax for the same length of time (three seconds), which is readily effected by lifting the prisms up and allowing the light to enter the eyes uninfluenced. The guiding sensation at once causes the relaxation to take place, so that the yellow spots may receive the

images. At the end of three seconds the prisms are again dropped before the eyes, when the interni again contract. Then a second time the relaxation is effected by lifting the prisms; and so on throughout every sitting, which should last from two to ten minutes, but should always be discontinued short of fatigue. The sittings should be repeated two or more times a day. While it will take weeks, if not months, to establish orthophoria, nevertheless this end can be attained, in suitable cases, by this method. It may be better in most cases to resort to the two methods of development, the taper and the prisms, each day, but not at the same sitting.

In resorting to the prism exercise, it would be more convenient to close the eyes, for the purpose of getting relaxation, than to lift the prisms; but when the eyes are closed the relaxation is slow to take place, and is rarely complete at the end of sixty seconds; whereas, when the prisms are raised, the guiding sensation effects, at once, complete relaxation, which continues till the prisms are again placed before the eyes. The rhythmic nature of the exercise is more perfect in the latter than in the former, and results are better necessarily.

The method of exercise of the interni by means of strong prisms, introduced by Deady, of New York, and later reintroduced and earnestly advocated by Gould, may have its merits, but certainly not in the line of muscle building. The good resulting from this method must come through excitation of the converging center, the third conjugate. An overdraft on a nerve-center may be endured for a time, but should be avoided, if possible. Ultimately, exhaustion would be expected to follow. At any rate, it would seem to be far better to change the condition of the muscle so that the normal nerve impulse would make them do their work properly. That a muscle can be made stronger by light rhythmic exercise, never carried to the point of fatigue, does not admit of a doubt.

Without endorsing the use of strong prisms, in exophoria, the method must here be given. The exercise begins at a point twenty inches distant from a lighted candle or gas jet, by placing before the eyes the strongest prisms, bases out, that can possibly be overcome. At once the light is carried from the patient, or the patient recedes from the light, until a distance of twenty feet intervenes. The prisms are then raised, when, of course, relaxation occurs. When again within twenty inches of the light, the prisms are lowered, and recession follows as before. Thus the exercise is continued from three to five minutes, the powerful contractions and full relaxations following each other every seven seconds. The periods of exercise are to be repeated several times a day. Very strong claims have been made for this

method, and there may be more in it than would appear from reasoning about it; but its most ardent advocates confine its use to the treatment of exophoria.

There are only these two methods of exercising the interni by means of prisms. The one is gentle rhythmic exercise by means of weak prisms with their bases out; the other method loads the convergence by means of the strongest prisms possible. The former is intended for the strengthening of the muscles themselves, while the latter is designed to stimulate the convergence center to greater activity. The advocates of the latter method claim that exophoria, in most cases, is purely innervational and should be cured by forced stimulation of the convergence brain-center, the third conjugate innervation center. That this center is susceptible to excessive stimulation cannot be denied, but it is doubtful if this should be done. It is certainly more rational to develop the interni so as to make them respond normally to the impulse that the brain-center can easily generate in its real, though it may be subnormal, state of development. If it were possible to enlarge the capacity of a brain-center, as it is possible to increase the size and power of a muscle, the Deady method would not be objectionable.

In high degrees of intrinsic exophoria, non-operative measures will be productive of but little good, and that little will be slow of accomplishment. Exophoria in the distance of 4° or more, and an exophoria in the near equal to the angle of convergence at that point, give little promise of yielding to non-operative means. An exophoria that gives diplopia in the distance under the red-glass test, is practically always a case for surgical treatment. All cases not showing good results, in a reasonable length of time, under non-operative measures, should be given the advantage offered by skilled surgery.

The object in view when exercising the interni in exophoria is to so develop them that they may respond normally to a normal nerve impulse.

Operative treatment of exophoria. Before any operation for exophoria is done, the possibility of a cure by non-operative means should be eliminated, and the condition of every intrinsic ocular muscle should be known. Complicating muscle imbalances must be taken into account, and, if possible, should be corrected by the operations for the exophoria. In uncomplicated cases of exophoria, and in cases complicated only by hyperphoria of one eye and cataphoria of the other, the operations must either diminish the tonicity of the externi or increase the tonicity of the interni. When the exophoria is complicated by a cyclophoria, not only must the muscle tonicity be altered, but the muscle plane must also be changed.

In sthenic exophoria the externi should be first subjected to the operation of partial tenotomy, with the view of reducing their tonicity. The case being uncomplicated, the tenotomy should be central. The operative effect should be equally divided between the two externi, and should not be so extensive as to reduce abduction below 8° or abversion below 50°. In no case of exophoria should a complete tenotomy of an externus ever be done, for the reason that the risk of reducing both the duction and version power below the normal would be too great. After the two partial tenotomies, any remaining exophoria that cannot be cured by non-operative measures should be still further relieved by a straightforward shortening of one or both interni, with the view of increasing tonicity without changing the muscle plane.

When there is a complication of hyperphoria and cataphoria only, the operations, whether partial tenotomies or shortenings, should be done as if no complication existed. At some other time the vertical error must be given the proper treatment.

A sthenic exophoria that is complicated by a plus cyclophoria should be treated with the view of lessening the tonicity of both externi and lowering their planes of action. This would be accomplished by cutting the upper and central fibers of each externus as nearly alike as possible, leaving the lower fibers intact. The three-fold effect of these two operations would be: (a) lessening or curing the exophoria; (b) correction, wholly or in part, of the plus cyclophoria; (c) the production of a double cataphoria.

A sthenic exophoria complicated by a plus cyclophoria and a right hyperphoria and left cataphoria should be subjected first to a partial marginal tenotomy of the externus of the hyperphoric eye. The operation of cutting the upper and central fibers of this externus would be attended by these three results: (a) lessening of the exophoria; (b) a partial or complete correction of the plus cyclophoria; (c) the production of a cataphoria equal to, or a little less than, the cataphoria in the other eye. If any remaining exophoria should still be complicated with plus cyclophoria and left cataphoria, the second operation should be a shortening of the left internus in such a way as to both increase its tonicity and elevate its plane of action. This would have three results: (a) still further diminishing, if not curing, the exophoria; (b) a further correction of the plus cyclophoria; (c) an elevation of the cataphoric eye so as to bring it as nearly as possible in the same horizontal plane with the eye that was primarily hyperphoric. Should the first operation cure the complicating plus cyclophoria, even if the hyperphoria were not cured, the remaining exo-

phoria should be relieved by a central partial tenotomy of the externus of the left eye, which would alter its tonicity without changing its plane of action.

Asthenic exophoria uncomplicated should be treated by straightforward shortening of both interni, the operative effect being as equally divided between them as possible. In this way their tonicity would be increased, but their planes of rotation would not be changed. The same operations should be done when the exophoria is complicated by hyperphoria and cataphoria. Operations for a lateral error should attempt the simultaneous correction of a vertical error only when there is a complicating cyclophoria.

Asthenic exophoria, complicated by a plus cyclophoria only, should have both conditions relieved by shortenings of both interni in such a way as to increase their tonicity and elevate their planes. The triple effect would be: (a) correction of the exophoria; (b) cure of the plus cyclophoria; (c) the production of a double hyperphoria. When the complication is not only a plus cyclophoria, but a right hyperphoria and left cataphoria as well, the first operation should be a shortening of the left internus in such a way as to both increase its tonicity and elevate its plane. These would be the effects of this operation: (a) correction, wholly or in part, of the exophoria; (b) a partial or complete cure of the cyclophoria; (c) the production of a double hyperphoria. If the internus of the right eye must be operated upon, the shortening must be straightforward, even if the two complications still existed; for an elevation of its plane would increase the hyperphoria while lessening the plus cyclophoria, and lowering its plane would increase the cyclophoria while diminishing the hyperphoria.

If a minus cyclophoria, which is rare, should alone complicate an exophoria, the marginal tenotomies of the externi would be below, and the shortenings of the interni would have to be done so as to depress their plane of rotation. If the minus cyclophoria with a hyperphoria and a cataphoria should complicate an exophoria, a lower marginal tenotomy of an externus should be performed only on the externus of the cataphoric eye; while a shortening of an internus with depression of its plane should be done only on the internus of the hyperphoric eye, for reasons that are apparent.

The chief object in operating for exophoria, whether the operation be partial tenotomies of the externi, for sthenic exophoria, or shortenings of the interni, for asthenic exophoria, is to so change the relative tonicity of these two muscles as to establish harmony between them.

The change of the plane of action, though of vast importance, depends solely on the existence of a complicating cyclophoria.

HYPERPHORIA AND CATAPHORIA.

These conditions can be studied intelligently only when the head is in the primary position, with the test object on the line of intersection of the extended median and horizontal fixed planes of the head. The object should be twenty feet distant from the eyes. If there is no imbalance of the vertically-acting muscles and the lateral recti are properly attached and the eyes are contained in orbits that have been normally developed, when the test object is fixed, the two visual axes will lie in the extended horizontal plane, with no tendency for either axis to rise above or dip below this plane. This will be shown under any one or all of the tests for determining the balance of the ocular muscles. Such a condition is vertical orthophoria.

Hyperphoria. Hyperphoria is a tendency of one visual axis to rise above this plane, the actual turning easily occurring as soon as the eye is freed from the control of the guiding sensation, by any one of the tests to be given further on.

Cataphoria. Cataphoria is a tendency on the part of one visual axis to fall below this plane, the tendency becoming a turning so soon as the image has been changed, in character or position, so that no effort at fusion will be made. Usually a hyperphoria of one eye is associated with a cataphoria of the other, and the two errors are practically equal. Occasionally there will be found a case in which there is a vertical orthophoria of one eye and a hyperphoria or cataphoria of the other. Less frequently there will be double hyperphoria or double cataphoria.

Any one of these errors makes it a difficult matter for the superior and inferior recti to obey the law governing them—to wit, they must keep the visual axes in the same plane, in order to help relate, properly, corresponding retinal points.

Causes. There are several conditions that may cause a vertical imbalance. Since malformation of the orbits has been emphasized, in recent years, as a cause of hyperphoria, this will be studied first. Only in the sense of one orbit's being higher or lower than the other, can a malformed orbit be the only cause either of a hyperphoria or a cataphoria. Fig. 30 represents the median plane of the head, A B; the horizontal plane of the head, C D; and the two eyes. The right one is in a normal orbit, so that its vertical axis *gh* is parallel with the median plane of the head and its transverse axis *ef* is contained in the horizontal plane of the head. The left eye is represented as contained

in a malformed orbit, in the sense that it is lower than the fellow orbit; therefore the contained eye is lower than its fellow, as is shown by its transverse axis *ef* lying below the fixed horizontal plane of the head, C D. It will be seen that the vertical axis *gh* is parallel with the median plane A B. The muscles of these two eyes may be supposed to be perfectly balanced. Under the phorometer test of the vertically-acting muscles, the right eye would show orthophoria, but the left eye would show cataphoria. In binocular fixation of a point lying in the extended horizontal plane of the head, the visual axis of the right eye, the muscles being in a state of equilibrium, would point to the object; while the visual axis of the left eye would have to be raised by the superior rectus and inferior oblique, so as to intersect its fellow at the point of view. Thus elevated, its vertically-acting muscles cannot be in a state of equilibrium. Under test this eye would drop into a state of equilibrium for all of its muscles and would thus

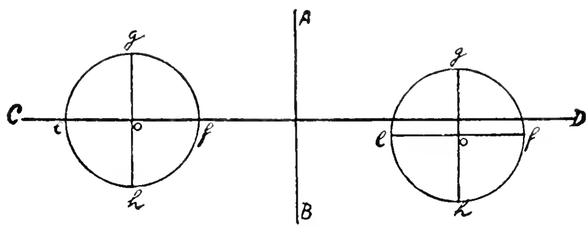


Fig. 30.

show cataphoria. No posing of the head would change the condition or lessen the error. The right eye under test would continue in its state of equilibrium, and would, therefore, show vertical orthophoria.

A figure could have been constructed showing the right eye in a normal orbit, with its axes properly related to the median and horizontal planes of the head; and the left eye in a malformed orbit, in the sense of its being higher than the fellow orbit, with its transverse axis *ef* above the fixed horizontal plane of the head, although its vertical axis *gh* would be parallel with the median plane. The right eye would show vertical orthophoria, but the left eye would show hyperphoria. No posing of the head can change the relationship that these two eyes bear to the two fixed planes of the head.

Fig. 31 represents malformation of both orbits in the sense that the right one is too high and the left one too low. The vertical axis of each eye is parallel with the median plane of the head, but the transverse axis of neither eye lies in the horizontal plane of the head; that of the right eye is above, while that of the left eye is below it, but

both are necessarily parallel with it. The malformation of the right eye would give to it hyperphoria, while the malposition of the left eye would give to it cataphoria. A state of equilibrium of the vertically-acting muscles (granted to be normal) of the right eye would place its axis above, but parallel with, the extended horizontal plane of the head; while the same muscular state of the left eye would place

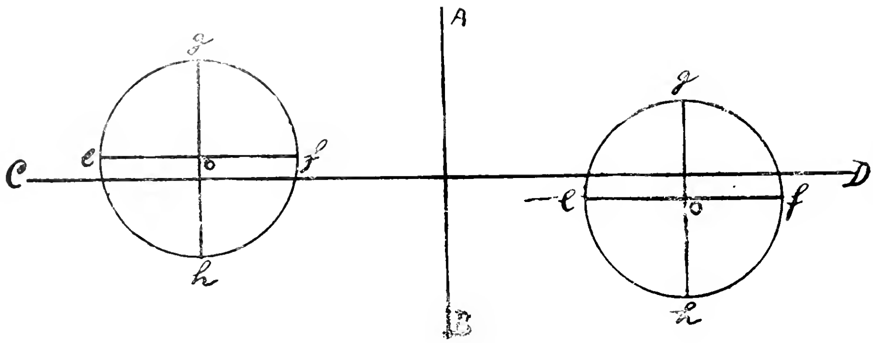


Fig. 31.

its visual axis below, but parallel with this plane. No pose of the head can help these eyes in the effort at binocular fixation.

Fig. 32 represents a pair of eyes that are set in malformed orbits, in the sense that both are too low; hence both of these eyes have their transverse axes below the horizontal plane of the head, but parallel with it. This kind of malformation gives a double cataphoria, which

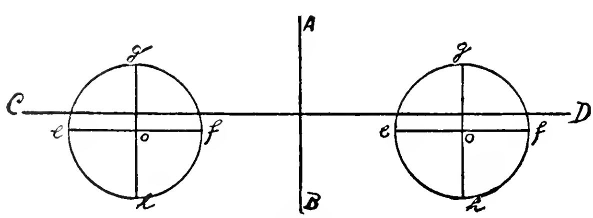


Fig. 32.

can be detected with a fair degree of readiness by means of the monocular phorometer, but is more certainly and more easily shown by the proof test of hyperphoria—a double prism, the use of which, for this purpose, will be described under the head "Tests." A pose of the head cannot bring the transverse axes of the eyes into the horizontal plane of the head, but it can make vision easier. The characteristic pose, in such cases, is an elevation of the chin. Such people are high-headed.

Fig. 33 represents a pair of eyes set in malformed orbits, in the sense that they are both too high. The vertical axes are parallel with the median plane of the head, but the transverse axes lie above the horizontal plane, though parallel with it. With the head in the primary position, a point in the extended horizontal plane and in the line of its intersection by the extended median plane cannot be fixed by these eyes without depression of the visual axes by contraction of the inferior recti, aided by the superior obliques. Under test, either one of these eyes not under control of the guiding sensation will turn up into the position of muscle equilibrium, showing a double hyperphoria.

In the study of all these figures, all of the muscles are supposed to be normal in development, correct in attachment, and perfectly innervated. A double hyperphoria and a double cataphoria caused by

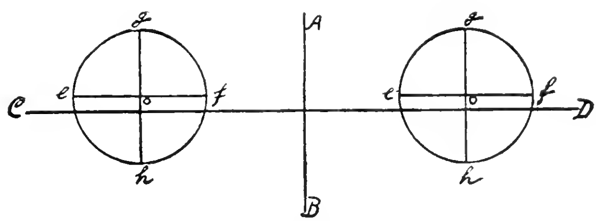


Fig. 33.

malformed orbits would have the line connecting the centers of the two eyes parallel with the horizontal plane of the head, hence the primary isogonal circle of such eyes would not be tilted. The horizontal retinal meridians would easily lie in this plane. A hyperphoria of one eye and a cataphoria of the other, or a vertical orthophoria of one eye and a hyperphoria or cataphoria of the other eye, having malformations of the orbits as the sole causative agent, will compel a complicating cyclotropia; for the center of one eye being lower or higher than the other, the line connecting these centers would form an angle with the horizontal plane of the head. This line fixes the position of the primary isogonal circle, therefore this circle must be inclined. In binocular single vision of such eyes the horizontal retinal meridians must be made to incline so as to lie in the inclined plane of the primary isogonal circle. This compensating cyclotropia is always towards the side of the lower eye. The angle of leaning of the vertical axes of such eyes, one towards, and the other from, the median plane of the head, would be the same as the angle between the horizontal plane of the head and the plane of the inclined isogonal

circle. The covering of one eye would relieve the eighth or ninth conjugate center, as the case may be, of the work of placing the horizontal meridians in the inclined plane of the primary isogonal circle, so that the vertical axes of both the seeing and the covered eye would become parallel with the median plane of the head. Resuming binocular vision would, at once, reexcite the necessary compensating cyclotropia.

The practical thought growing out of the above observation is that, in correcting the astigmatism of eyes that are not level, these axes must be shifted from the position found in the monocular test, in the direction of the lower eye, through an arc corresponding to the angle of inclination of the line connecting the centers of the two eyes.

It should be remembered that other causes of hyperphoria and cataphoria may exist when eyes are set in malformed orbits, and that the other causes may show themselves in an increase of the error caused by the malformation of the orbit, or may neutralize it, or may even reverse it. To illustrate: the right orbit may be normal, the contained eye having its vertical and transverse axes properly related to the median and horizontal fixed planes of the head; while the left orbit may be too low, so that the contained eye has its transverse axis below the horizontal plane of the head (see Fig. 30). As a consequence, the muscles being well balanced, there will be a left cataphoria; but if the left superior rectus is too strong for its opposing inferior rectus, the cataphoria of orbital causation either will be neutralized or there will be a left hyperphoria. But even in these cases there will be the necessity for compensating cyclotropia.

When malformation of the orbits is the only cause for vertical imbalances, the resulting errors may be said to be pseudo-hyperphoria and pseudo-cataphoria. The treatment of such errors should be by means of prisms in positions of rest, of such strength as to fully correct the errors, but these prisms cannot correct the compensating cyclotropia, nor can any procedure do so.

Malplaced lateral recti. There is no direct connection between the brain-center for the ciliary muscles and those centers controlling the muscles that elevate and depress the eyes; so that, through these muscles, a focal error cannot cause a hyperphoria or a cataphoria. It cannot be denied, however, that convex lenses given to correct hyperopia, sometimes cure a hyperphoria or a cataphoria. Such cases have always had a pseudo-esophoria which, likewise, was cured by the convex lenses. It is clear that in such cases one internus is attached too high or the other internus is attached too low, so that the one eye, on being turned in, is also turned up; while the other eye, on being turned in, is also turned down. The same agent (convex lenses) has

relieved the in-turning (pseudo-hyperphoria) and the down-turning (pseudo-cataphoria). Both interni attached too high would give, under the same conditions, a double pseudo-hyperphoria; while both interni attached too low would give a double pseudo-cataphoria. There would also be a complicating cyclophoria, which will be studied more fully further on.

In the same way it could be shown how a pseudo-exophoria, because of too high or too low attachment of one or both externi, might cause a pseudo-hyperphoria or cataphoria, one or both, or either in the double form, all of which would be relieved by concave lenses.

Intrinsic. Hyperphoria and cataphoria, in the great majority of cases, are intrinsic, or inherent, in character. They are never pseudo except when caused by pseudo-esophoria and pseudo-exophoria, or malformed orbits.

The cause of an intrinsic vertical error may reside wholly in the interni, but only when there is an intrinsic esophoria or an intrinsic exophoria. In such cases of esophoria one or both interni are attached too high, or one or both are attached too low, or one is attached too high and the other is attached too low. In the one, the esophoria would cause a double hyperphoria and a minus cyclophoria; in the second case the esophoria would cause double cataphoria and plus cyclophoria; and in the last case the esophoria in one eye would cause a hyperphoria and a minus cyclophoria, and in the other a cataphoria and a plus cyclophoria. How to deal with such interni has been pointed out in the section on esophoria.

Intrinsic exophoria, in which the externi are attached too high, will cause double hyperphoria and plus cyclophoria; if both interni are attached too low, the exophoria will cause double cataphoria and minus cyclophoria. If one internus is too high and the other is too low, the exophoria of the former would cause hyperphoria and plus cyclophoria; the exophoria of the latter would cause cataphoria and minus cyclophoria. How to deal with the externi in such cases has been set forth in the section on exophoria.

Hyperphoria and cataphoria, in the greater number of cases, are caused by imbalance of the vertically-acting muscles—the supervertors and subvertors, which are the superior recti and inferior obliques and the inferior recti and the superior obliques. When the cause is either in the straight or oblique supervertors or in the straight or oblique subvertors, the error is always inherent, and never pseudo.

Double hyperphoria. This condition may be caused by the two superior recti being hyper-developed, or by a subnormal development of the inferior recti; or it may be caused by the superior recti having

their attachments too near the corneo-scleral junction, or by the inferior recti having their attachments too far removed from the corneo-scleral junction; or it may be that the first conjugate innervation center is normally so endowed as to send a more powerful impulse to the superior recti than goes to the inferior recti from the second conjugate innervation center. If either of these conditions is the cause of a double hyperphoria, there will also be a minus cyclophoria, independent of any imbalance of the obliques.

The superior and inferior recti may be well balanced, and the externi and interni may have ideal attachments, and yet there may be a double hyperphoria. The cause would be found in imbalance of the obliques, the inferior having the advantage over the superior, either because the former are more highly developed or because they are attached nearer the posterior pole or because the seventh conjugate innervation impulse is more intense than that from the sixth conjugate innervation center. In either case the double hyperphoria would be associated with plus cyclophoria.

In double hyperphoria caused by the superior recti being too strong, the nervous tension of the inferior recti would counteract both the hyperphoria and the minus cyclophoria, while nervous tension of the superior obliques would help to counteract the hyperphoria, but would augment the minus cyclophoria. It is reasonable, therefore, to conclude that the counteracting nerve impulse in such a case is sent only to the inferior recti. Depressing the chin—a downcast face—would help relieve the inferior recti of nervous tension.

In double hyperphoria caused by the inferior obliques being too strong, nervous tension of the superior obliques would counteract both the hyperphoria and the plus cyclophoria, while nervous tension of the inferior recti would help to counteract the hyperphoria, but would increase the plus cyclophoria; hence the conclusion that the counteracting impulse, in such a case, is sent only to the superior obliques. Such a patient would instinctively elevate the chin—carry a high head—to relieve the nervous tension of the superior obliques. The most advantageous position of the eyes for the in-torting action of the superior obliques is a depression of the visual axes below the fixed horizontal plane of the head; the greater this depression of the visual axes (elevation of the head), the more powerful the in-torting action of the superior obliques.

Double cataphoria. This condition may be the result of hyper-development of the inferior recti or sub-normal development of the superior recti, or it may result from the inferior recti having their attachment too far forward or from the superior recti being attached

too far back; or it may be caused by a more powerful impulse sent from the second conjugate innervation center to the inferior recti than is generated by the first conjugate center for the superior recti. In either case the double cataphoria will be associated with plus cyclophoria. Nervous tension of the superior recti will counteract both the cataphoria and the plus cyclophoria; while nervous tension of the inferior obliques would counteract the cataphoria, but would increase the plus cyclophoria. Hence, in cases like the above, the correcting nerve impulse must be sent only to the superior recti. The position of the eyes most favorable for effective action of the superior recti is a depression of the visual axes below the horizontal plane of the head; hence such patients will carry their heads high, so as to lessen the nervous tension of the superior recti.

Double cataphoria may be caused by imbalance of the obliques, the superior being stronger than the inferior, either because the former are hyper-developed or the latter are subnormally developed, or because the former are attached nearer the posterior pole, or because the sixth conjugate innervation is more powerful than the seventh. In either case the double cataphoria would be associated with minus cyclophoria. The corrective nerve impulse would be sent to the inferior obliques, which would counteract both the double cataphoria and the minus cyclophoria. The position of the eyes most favorable for corrective action of the inferior obliques is an elevation of the visual axes above the extended horizontal plane of the head; hence such patients would have their faces downcast, for this pose of the head would help to relieve the nervous tension of the inferior obliques.

Hyperphoria of one eye and cataphoria of the other, independent of malformation of the orbits and faulty attachments of the lateral recti muscles, are always inherent in the vertically-acting muscles, and never innervational. For convenience of study the right eye will be considered as hyperphoric and the left eye as cataphoric, although the reverse is often found. The right hyperphoria is due to the fact that the superior rectus is too strong for its direct antagonist, the inferior rectus, or that the inferior oblique is too strong for the superior oblique; or both of these conditions may unite in the development of the hyperphoria. If the superior rectus alone is the cause of the hyperphoria, it is because this muscle is hyper-developed or that the inferior rectus is of subnormal development, or that the superior rectus is attached too near the cornea or that the attachment of the inferior rectus is too far removed from the cornea.

The hyperphoria would be sthenic if the superior rectus is hyper-developed or is attached too near the cornea; it would be asthenic if

the inferior rectus is subnormally developed or is attached too far away from the cornea. In either case the hyperphoria would manifest itself in association with minus cyclophoria.

If the inferior oblique alone is the cause of the hyperphoria, it is because of hyper-development of this muscle or a subnormal development of the superior oblique; or because the inferior oblique is attached too far behind the equator or the superior oblique is attached too near the equator. The hyperphoria thus caused is sthenic in cases in which the inferior oblique is hyper-developed or is attached too far behind the equator; it is sthenic in those cases in which the superior oblique is subnormally developed or is attached too close to the equator. In either condition the hyperphoria would show itself in association with plus cyclophoria.

When the hyperphoria manifests itself unassociated with either minus or plus cyclophoria, it becomes evident that both the superior rectus and inferior oblique enter into the causation.

The left eye under test will show cataphoria, usually the same in quantity as the hyperphoria of the right eye. The cataphoria is caused by either a too powerful inferior rectus or a too powerful superior oblique; or both of these muscles may unite in the production of the cataphoria.

In a case in which the inferior rectus alone is the causative agent, it is either hyper-developed or has its attachment too close to the cornea; or its direct antagonist, the superior rectus, is subnormally developed or is attached too far away from the cornea. The cataphoria would be sthenic if the inferior rectus is either hyper-developed or is attached too near the cornea; it would be asthenic if the superior rectus is under-developed or has its attachment too far removed from the cornea. In either case the cataphoria would be associated with a plus cyclophoria.

In a case in which the superior oblique is the sole cause of the cataphoria, it is either because it is hyper-developed or because it has its attachment too near the posterior pole; or because its direct antagonist, the inferior oblique, is subnormally developed or is attached too near the equator. The resulting cataphoria is sthenic in those cases in which the superior oblique is either hyper-developed or is attached too near the posterior pole; it is asthenic when the inferior oblique is under-developed or is attached too near the equator. In either case the cataphoria would be associated with a minus cyclophoria. Cataphoria will be unassociated with either plus or minus cyclophoria only when both the inferior rectus and superior oblique are united in the causation.

Nervous tension of the inferior rectus counteracts the right hyperphoria, if caused by the superior rectus; while nervous tension of the superior rectus will counteract the left cataphoria, if caused by the inferior rectus. Not only will the right hyperphoria and left cataphoria be thus neutralized, but the minus cyclophoria of the right and plus cyclophoria of the left would be suppressed by the nervous tension of the same muscles. The corrective impulse would come not from one conjugate center, as in double hyperphoria and double cataphoria, but from two separate centers.

Nervous tension of the superior oblique counteracts the right hyperphoria which is caused by the inferior oblique, while nervous tension of the inferior oblique will counteract the left cataphoria that is caused by the superior oblique. The plus cyclophoria of the right eye and the minus cyclophoria of the left eye will be suppressed by the nervous tension of the same muscles that counteract the hyperphoria and cataphoria.

Tests. The phorometer, with perfectly adjusted prisms and spirit level, alone can be depended on in testing for hyperphoria and cataphoria. The slightest error in testing will be followed by bad results in practice. In attempting to test for these errors by means of a displacing prism with its axis horizontal, held in the hand, one would have to be very careful or the axis would be slightly inclined in one direction or the other; so that, if the eye under test is hyperphoric and the temporal end of the prism inclines down, the error will be exaggerated, and if it inclines upward, the hyperphoria would be neutralized more or less completely, or even a cataphoria might be shown.

For reasons already given, the rod test is not to be trusted implicitly, but it is much to be preferred over the hand-prism test, or even the prism when set in the trial frame of the refraction case. The test object being a candle, a rod held with its axis vertical before one eye will show the streak of light which, in orthophoria, should pass directly through the blaze seen by the other eye; in hyperphoria, the streak would pass below the blaze, while in cataphoria it would pass above the blaze. In the low degrees of vertical heterophoria, the streak falling on the area of binocular fusion (Fig. 29) will excite some effort, however small, at fusion. In the higher errors, the prism used for measuring the amount of the error, by throwing the streak on the fusion area, would excite some effort at fusion. When the rod is the means of testing, the error is never shown in excess, and for this reason is more safe than accurate.

The use of the plus 13 D. lens before one eye, if not worthy of trust

in the examinations for esophoria and exophoria, would certainly be less trustworthy in examinations for hyperphoria and cataphoria.

In high degrees of a vertical error the plane red glass held before one eye will cause diplopia, the red light below in hyperphoria and above in cataphoria. When the red image is entirely outside the area of binocular fusion, the full error will be shown, but cannot be accurately measured, for the reason that the rotary or other prism that carries the red image into the fusion area, at once excites some effort at fusion. Like the rod test, the red-glass test will mislead only in that it will not show, even on careful measurement, the full error.

The cover test will show the vertical errors, but no one would think of basing the treatment of a case on this test.

Monocular phorometer. Any of the standard phorometers may be used in testing for vertical heterophoria, but in this the monocular instrument is most useful and trustworthy. The 10° prism, base in, should be placed in the cell behind the rotary prism; the controlling screw should be vertical, and the index should stand at zero. The instrument should be perfectly level. The patient's head should be in the primary position. The test object should be a white spot on a black background, and should be distant twenty feet. With the instrument before the right eye there will appear to be two spots, the true one to the left and the false one to the right. If they are too widely separated, as in cases that are esophoric, the 6° prism should be substituted for the 10° prism. The patient should constantly fix the true spot, and by indirect vision alone should locate and relate the false spot. If the eye is hyperphoric, the false spot will be lower than the true; and since its image is not on the area of binocular fusion, the full error will be shown. The index of the rotary prism moved upward will accurately measure the error; for in carrying the false object up to the level of the true, the image of the former is not made to invade the fusion area, provided the true object alone has been fixed throughout the test.

The vertical imbalance of one eye having been taken, the phorometer should be turned in front of the other. Precisely the same steps should be taken in determining the condition of its vertically-acting muscles. Hyperphoria having been found in the eye first tested, the fellow eye, as a rule, will be found cataphoric. The false object will appear higher than the true. The index of the rotary prism should be carried downward until the false object reaches a level with the true object. The quantity of the error, as indicated on the scale, should be noted. In the greater number of cases the degree of cataphoria will be the same as the hyperphoria of the other eye.

One eye having shown hyperphoria, the other may show vertical orthophoria or even hyperphoria. The eye under test, seeing the false object by indirect vision, does not receive any fusion stimulus; hence it always turns into the position of equilibrium of all its muscles. For this reason it is just as easy to determine the existence of a double hyperphoria, with the monocular phorometer, as it is to ascertain the existence of any other form of heterophoria. The patient must be impressed with the absolute importance of always fixing the true object—that is, must see it by direct vision.

Proof test. Whether one or the other of the tests referred to above should be adopted, the proof test for vertical imbalance should not be neglected. Errors that may have crept in because of carelessness of the operator or indifference of the patient can be eliminated easily by the proof test. The means of proving is the Maddox double prism (4° to 6° each). This should be held in the hand first before one eye and then the other, so that the line of union of the prism bases shall be horizontal. The fixing eye should be the one not under test. The prism should be moved up and down before the eye under test, so that one moment the false object would be seen below the true and the next moment above it, but always by indirect vision. If the distance from the true to the false object is the same when below as it is when above, there is vertical orthophoria. If there is hyperphoria, the false object, when seen through the upper prism, will be closer to the true object, by twice the amount of error, than when seen through the lower; while the reverse will be true, if there is cataphoria. In double hyperphoria the objects will be closer together for each eye when the false object is seen through the upper prism; while in double cataphoria the false object, when seen through the lower prism by each eye, will be nearer the true object than when seen through the upper prism. If there is hyperphoria of one eye and cataphoria of the other, when the double-prism proof test is applied to the hyperphoric eye, the false object seen through the upper prism will be close to the true, and will be farther removed from it when seen through the lower prism. On shifting the test to the other eye, the false object seen through the lower prism will be nearer the true than when it is seen through the upper prism. The double prisms should be of equal strength, and each should be strong enough to throw the image of the test object entirely above or below the limits of the field of fusion.

Doak, of Nashville, Tenn., has devised a test for vertical imbalances that not only detects and measures the error, but is also in itself a proof test. By this test the kind of error is at once detected, but its quantity is not known until the proof feature has been applied. The

delicacy of the test is shown by an apparent doubling of the quantity of the error. This delicacy makes it dangerous only when the operator forgets that the apparent error is twice that of the real error. For making this test the monocular phorometer must be placed before one eye, and in the cell next to the eye must be placed either the 10° or 6° prism, base toward the nose. The controlling screw must be vertical, and the index, at the beginning, should stand at zero. The instrument must be level. The patient must hold before the other eye a double prism in such position as to make the test object (white spot on a black background) double for that eye, the one directly above the other, and the two should be 12° apart—that is, each of the double prisms should be 6°. With the double prism thus adjusted, these two spots must be seen by indirect vision, while the single spot seen by the other eye should be observed by direct vision. Because of the displacing prism behind the phorometer, the single object will not be in line with the other two; and when it is seen by direct vision, the other eye will be so turned that the vertical imaginary line connecting the two false objects will fall to the nasal side of the fusion area, so that, as the test proceeds, there will be made no effort at fusion. The eye behind the double prism will be wholly off its guard. The moment the single object is fixed, the patient can usually say whether or not it would be halfway between the other two objects, if it were in line with them. If the middle object is seen nearer the lower, that eye is hyperphoric; if nearer the upper, it is cataphoric. The proof feature of the test results from the use of the rotary prism. When the screw is turned so as to carry the index upward, the patient is asked to speak the moment the single object is in a horizontal line with the upper of the two false objects. The extent of the rotation is noted, after which the rotary prism is again made neutral. The next step is to carry the index of the rotary prism downward until the patient says that the single object is in a horizontal line with the lower of the two false objects. The extent of downward rotation is now noted. If the two arcs traversed by the index are equal, there is undoubtedly vertical orthophoria of this eye. If the lower arc is 5° and the upper arc is 7°, this eye is certainly hyperphoric—not to the extent of the difference between these two arcs, which would be 2°, but only half this amount—viz., 1°. If the upper arc is 5° and the lower arc is 7°, there is cataphoria—not of 2°, but of 1°. The reason for saying that the real vertical error is only one-half of the apparent error is clear. Since each of the double prisms is 6°, the double objects seen through them, when the base-line is in the extended horizontal plane of the head, are 12° apart. The extended horizontal plane of the head cuts the

imaginary line connecting the two false objects at the midway point—6° from each. If the displaced object seen by direct vision with the other eye is in this plane, it would have to be carried up or down by the rotary prism just 6° to be placed in a horizontal line with the one or the other of the false objects, hence the eye would be orthophoric vertically. If the true object is 1° below the extended horizontal plane of the head, it will have to be carried downward by the rotary prism only 5° to be placed in a horizontal line with the lower object, while it would have to be carried upward 7° to stand in a horizontal line with the upper object. Thus it is clear that the hyperphoria shown by this test is one-half the difference between the arcs traversed by the index of the phorometer in placing the true object in a horizontal line first with the one false object and then with the other, the index each time starting from zero. Throughout the entire test the single object must be fixed. Although this test is in a sense binocular, it is probably better than any other test for two reasons: (a) It doubles the real error, so that a small error will be less likely to be overlooked; (b) this test proves itself.

The eye under the Doak test is the one behind the rotary prism. Both eyes should be subjected to the same test.

The duction and version power of the superior and inferior recti of both eyes must be taken in order to determine whether the hyperphoria and cataphoria are sthenic or asthenic, for on this knowledge must depend the treatment of the case.

If the super-duction is less than 3° and the super-version is 33° or less, the hyperphoria is asthenic; if sub-duction is less than 3° and sub-version is below 50°, the cataphoria is asthenic. If super-duction is more than 3° and super-version is greater than 33°, the hyperphoria is sthenic; if sub-duction is more than 3° and sub-version is greater than 50°, the cataphoria is sthenic.

Complications. Focal errors do not complicate vertical heterophorias, except in cases in which there is pseudo-esophoria or pseudo-exophoria with too high or too low attachments of the lateral recti muscles. A vertical error thus caused is pseudo in character and is cured, as is also the lateral pseudo-error, by correction of the focal errors.

The only complication that must always be thought of in the study of hyperphoria and cataphoria is cyclophoria; for by this complication is determined the treatment, surgical or otherwise, of these errors. How to find and measure this all-important complication will be set forth further on. If a hyperphoria is only complicated by esophoria

or exophoria or by any focal error, all these troubles must be treated as if they existed alone.

Symptoms. Any and all of the symptoms mentioned in the section on heterophoria may be caused by vertical imbalance. There is no facial expression that can be dignified as diagnostic of hyperphoria and cataphoria. There are poses of the head peculiar to both double hyperphoria and double cataphoria. High-headedness is a symptom of double hyperphoria when the inferior obliques cause the error, and is just as certainly a sign of double cataphoria when the inferior recti are the cause of the error. The most favorable position of the eyes for effective action of the weak superior obliques and weak superior recti under a corrective nerve impulse is a depression of the visual axes below the extended horizontal plane of the head, or (what is the same thing) elevation of the extended horizontal plane of the head.

The downcast look is a sign of double hyperphoria when the error is caused by the superior recti, and of double cataphoria when the error is caused by the superior obliques.

The most favorable position of the eyes for effective action of weak inferior obliques and weak inferior recti, under a corrective nervous impulse, is an elevation of the visual axes above the extended horizontal plane of the head, or (what is equal to it) a depression of the horizontal plane of the head. Very rarely is double hyperphoria caused by the inferior obliques, and still more rarely is double cataphoria caused by the two superior obliques, therefore a high-headed person may always be judged a double cataphoric, and one with a downcast head a double hyperphoric.

A tilting of the head toward one shoulder or the other occurs only in cases in which there is a hyperphoria of one eye and a cataphoria of the other, complicated by either plus or minus cyclophoria of both eyes, and never in simple cases of hyperphoria. The hyperphoria and cataphoria are not the cause of the tilting of the head; but the cause is the complicating cyclophoria. If the complication is plus cyclophoria, the head will be tilted toward the cataphoric side. In a case of this kind, tilting the head elevates the hyperphoric eye and depresses the cataphoric eye; so that to fix an object that would be in the extended horizontal plane of the head, if the head were erect, makes it necessary that the visual axis of the eye that is higher shall be depressed and that the visual axis of the eye that is lower shall be elevated, so as to make them intersect at the object. Depression of the visual axis of the hyperphoric eye places the eye in such a position (elevated posterior pole) as to give to the superior oblique, under

the whole of the stimulus of the sixth fusional innervation, its greatest torsioning power, which would enable it easily to parallel the vertical axis of the eye with the now-inclined median plane of the head. The hyperphoria, in such a case, is due largely to the inferior oblique, and the plus cyclophoria is wholly caused by it. The elevated posterior pole of the eye, made necessary by the tilting of the head, places the inferior oblique at a disadvantage to the weak superior oblique; hence, the greater ease with which both the hyperphoria and the plus cyclophoria are counteracted.

The cataphoria of the other eye must be caused by the inferior rectus, and the same muscle most probably causes the whole of the plus cyclophoria of this eye. The corrective stimulus most likely comes from the first fusional innervation center and is wholly expended on the superior rectus of the cataphoric eye (no stimulus is needed for the superior rectus of the hyperphoric eye), enabling it to counteract both the cataphoria and the plus cyclophoria. Its action is not favored by position. A corrective stimulus sent to the superior oblique would lessen the cyclophoria, but increase the cataphoria; therefore it is reasonable to conclude that none is sent to it.

In a case of hyperphoria of one eye and cataphoria of the other, complicated by a minus cyclophoria, the head is tilted toward the hyperphoric side. The cataphoric eye is elevated, the hyperphoric eye is depressed, by this position of the head; so that the visual axis of the higher eye must be depressed and that of the lower eye must be elevated, so as to intersect at a point that would be in the extended horizontal plane of the head, if it were erect. In this case the hyperphoria and cyclophoria must be due to the superior rectus of that eye, while the cataphoria and the minus cyclophoria of the other eye must be due to its superior oblique. The corrective impulse of the hyperphoria must be sent to the inferior rectus which is favored in its action by the necessary elevated position of its visual axis. It receives the impulse that comes from its second fusional innervation center. Thus are counteracted both the hyperphoria and the minus cyclophoria.

The cataphoria and the minus cyclophoria of the other eye are counteracted by a corrective nervous impulse that is sent to its inferior oblique whose action is not favored by the position that this eye must assume—an elevated posterior pole.

From what has been said above it will be observed that the tilting of the head toward the cataphoric side when there is plus cyclophoria, and toward the hyperphoric side when there is minus cyclophoria, is favorable only to the muscle that must correct the double error of the

hyperphoric eye, thus showing that the depressor muscles are in greater need of the help that comes from posing. The tilting is really unfavorable to the muscle that must correct the double error of the cataphoric eye. It may be that a nervous impulse gets a readier response, in unfavorable positions of the head, from the muscles that elevate the eyes than from those that depress them. It is well known that when the eyes are closed in sleep, or even in meditation, they turn slightly up; and the same is true under anesthesia that is not profound. This peculiar endowment of the supervertors seems to be necessary in order that the cornea may be carried instantly, for protection, into the position of greatest security.

It is doubtful if there is a symptom or sign, other than the posing of the head, that is peculiar to vertical imbalance. Excessive secretion of tears may be associated, in some unaccountable way, with hyperphoria and cataphoria.

Vertical imbalance associated with pseudo-esophoria or pseudo-exophoria may be dependent on it; and if so, it should be relieved by the same lenses that cure the lateral pseudo error.

Since a double hyperphoria may be caused by abnormal action of the inferior obliques, excited by oblique astigmatism with the meridians of greatest curvature converging above, and since double cataphoria may be caused by abnormal action of the superior obliques, excited by oblique astigmatism with the meridians of greatest curvature diverging above, these errors may be relieved, in such cases, by the correcting plus or minus cylinders.

Inherent vertical imbalance is made neither better nor worse by the lenses that correct focal errors. These must be treated by exercise, by prisms in positions of rest, or by operation.

Exercise. Double hyperphoria may be treated by exercise of the inferior recti, which is best done by looking straight ahead and then down to an object on the floor five or six feet distant, then again straight ahead and then down again, repeating this at regular intervals of three seconds. This straight-forward-to-floor exercise should be stopped short of fatigue, and should not be continued longer than ten minutes. One exercise a day is sufficient.

The exercise for double cataphoria is straight-forward-to-ceiling exercise, and should be carried out in the same manner as the straight-forward-to-floor exercise.

Prism exercise alone is applicable when there is hyperphoria of one eye and cataphoria of the other. The prisms with which to begin the exercise should be weak, and gradually stronger ones should be used, but they should never be stronger than 2°. Except for the cost,

the prisms should be in pairs of equal strength. The hyperphoric set shown in the accompanying cut (Fig. 34) consists of five prisms, as follows: $\frac{1}{4}°$, $\frac{1}{2}°$, $1\frac{1}{2}°$, and $2°$. The apex of the prism must point toward the muscle to be exercised—that is, it must be down for the hyperphoric eye and up for the cataphoric eye. When the prisms are of unequal strength, after three or four days' use they should be transferred and the exercise continued for three or four days longer. Now the weaker prism ($\frac{1}{4}°$) may be removed and the $1°$ prism put in its place. At the proper time the $\frac{1}{2}°$ prism and the $1°$ prism should be transferred, and the exercise should be continued with them for three days, when the $\frac{1}{2}°$ prism should be removed and the $1\frac{1}{2}°$

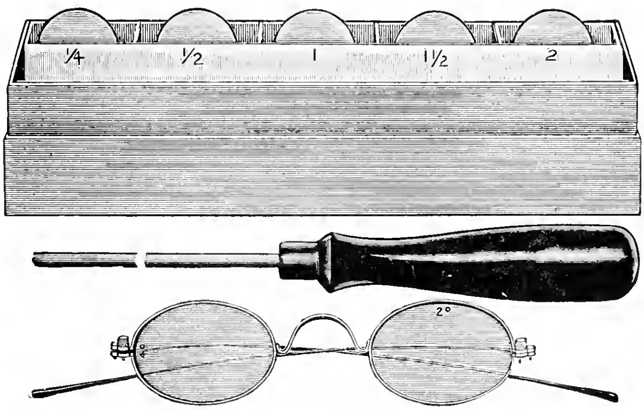


Fig. 34.

prism put in its place. The substitution should thus continue until the $1\frac{1}{2}°$ and $2°$ prisms are in the frames. The exercise should be continued indefinitely with these prisms, transferring them from side to side at regular intervals, always placing apex down for the hyperphoric eye and apex up for the cataphoric eye. The muscles should be exercised rhythmically by lowering and raising the frames containing the prisms, at intervals of three seconds. The exercise should be stopped short of fatigue and need not be continued longer than ten minutes. Once a day is sufficiently often to exercise. The object of fixation while exercising should be twenty feet distant, and should be sufficiently sharp in outline and bright to excite ready response of the muscles for the purpose of fusing the two displaced images.

Rest prisms. Relieving prisms for vertical imbalance are often of great use. Hyperphoria and cataphoria, uncomplicated, of less than $1\frac{1}{2}°$, should be relieved, if possible, either by exercise or by rest prisms. Cases in which these errors are as great as $2°$ or greater,

whether complicated or not, may obtain some relief from non-surgical means, but cannot be cured short of operations. If the vertical errors are as low as 1° and there is a complicating cyclophoria, surgery is the thing indicated.

The sub-ducting muscles stand in greater need of rest prisms than do the super-ducting muscles, for the reason given in the study of the posing of the head. If there were no other reason, it would be good practice in many cases, not complicated with minus cyclophoria, to apply the whole prismatic correction to the hyperphoric eye; and certainly this should be the practice if there is a complicating plus cyclophoria, however small in quantity. The superior rectus raising the eye to overcome the effect of the prism, in the interest of binocular single vision, torts it in, thus aiding the superior oblique to parallel the vertical axis of the eye with the median plane of the head.

In the few cases of hyperphoria and cataphoria that are complicated by minus cyclophoria, the whole of the prismatic effect should be applied to the cataphoric eye. The prism, with its base up before this eye, calls into action the inferior rectus in the interest of fusion; and thus aid is given the inferior oblique in its efforts to parallel the vertical axis of the eye with the median plane of the head.

Those cases of hyperphoria and cataphoria that are not complicated by cyclophoria will be given more comfort if the greater part (two-thirds) of prismatic effect is applied to the hyperphoric eye, than would be given if this rule were reversed, or even if the effect were equally divided between the two eyes.

If the rules given above are observed, many cases will take even a full correction of the hyperphoria, and not less than half the full correction should ever be given. The purpose may be attained either by prisms or lenses rendered prismatic by decentration.

Double cataphoria that causes the patient to hold his head too high should be given prisms or prismatic lenses, bases up, so as to let them assume a more nearly normal position of the head, provided there is no complicating plus cyclophoria. The effect should be equally divided between the two eyes.

Patients suffering from double hyperphoria should be given prisms or prismatic lenses, bases down, except when there is a complicating minus cyclophoria. These would enable the patient to carry his head comfortably in a more nearly erect position.

Hyperphoria, single or double; cataphoria, single or double; and hyperphoria of one eye and cataphoria of the other, caused by malformation of the orbits, should always be given full prismatic correction of the error found in each eye.

Operative treatment. A double hyperphoria that cannot be relieved by prisms or by straight-forward-to-floor exercise, to the extent of enabling the patient to carry his head erect, instead of downcast, should be subjected to a partial tenotomy of both superior recti. If there is no complicating minus cyclophoria, the tenotomies should be central; but should this complication exist—as it would if the superior recti are wholly at fault—the tenotomies should be peripheral, including only the temporal fibers. Should there be a complicating plus cyclophoria—as there would be if the inferior obliques were wholly to blame for the double hyperphoria—peripheral tenotomies of the superior recti should be done, including only the nasal fibers. In either case, the operative effect should be equally divided between the two muscles.

A double cataphoria does not so urgently demand operations, for high-headedness is not so objectionable as the downcast look. The position of the head in double cataphoria is more favorable to the respiratory act than is the position caused by double hyperphoria—another reason why operative interference is less urgent in double cataphoria. The lid pressure—pressure of the upper lids against the globe—is much less in double cataphoria than in double hyperphoria. Since great lid pressure is probably more favorable to the retention and development of germs, especially the trachoma germ, as suggested by Stevens, there is an additional reason for operating more frequently for double hyperphoria than for double cataphoria.

Straight-forward-to-ceiling exercise, or prisms with their bases up, should always be tried in cases of double cataphoria; but should these fail to enable the patient to carry his head in the natural, erect position, a partial tenotomy of both inferior recti should be done, and these operations should be central, unless there is a complicating cyclophoria. In cases in which there is a complicating plus cyclophoria—as there would be if the double cataphoria is caused by the inferior recti—peripheral tenotomies should be done, including only the temporal fibers. In those cases complicated by a minus cyclophoria, the superior obliques are the cause; but since these muscles cannot be, or ought not to be, operated upon, peripheral tenotomies of the inferior recti, including only the nasal fibers, should be done. The operative effect should be equally divided between the two inferior recti. Great care should be exercised, in operating for double cataphoria, not to convert it into a double hyperphoria. Operations on the inferior recti are as easily done as on the superior recti.

Since double cataphoria is preferable to double hyperphoria, there is good reason for always operating first on the superior rectus of the

hyperphoric eye in cases in which there is hyperphoria of one eye and cataphoria of the other. While the tenotomy should never be complete, it should be more extensive when done with the view of lowering the hyperphoric eye than when done for elevating the cataphoric eye; hence, the reason for doing the first operation as set forth in the beginning of this paragraph. After the first operation, the remaining imbalance must be corrected by a partial tenotomy of the inferior rectus of the cataphoric eye. As in the lateral heterophorias, so in the vertical errors, tenotomies are indicated only in the sthenic forms. A super-duction of 3° or less should never be diminished by lessening the tonicity of a superior rectus; and a sub-duction of 3° or less likewise contraindicates a tenotomy. An asthenic hyperphoria and cataphoria demands, first of all, a shortening of the inferior rectus of the hyperphoric eye, by means of which the greater part of the effect should be accomplished, the remaining part of the imbalance to be corrected later by a shortening of the superior rectus of the cataphoric eye.

In all cases of hyperphoria and cataphoria, uncomplicated by cyclophoria, the operations, if partial tenotomies, should be central; and if shortenings, should be straight-forward, so as not to change the plane of rotation. The complication of plus cyclophoria calls for a peripheral tenotomy of the superior rectus of the hyperphoric eye, including only the nasal fibers, and a peripheral tenotomy of the inferior rectus of the cataphoric eye, including only the temporal fibers. These two operations should be as nearly co-extensive as possible, because of the desire to correct the cyclophoria. Should a case of this character be asthenic, the inferior rectus of the hyperphoric eye should be shortened in such a way as to carry its plane of rotation farther in, and the superior rectus of the cataphoric eye should be so shortened as to carry its plane of rotation farther toward the temple. The operative effect should be equally divided between the two muscles.

The complication of minus cyclophoria, which is rare, indicates a peripheral tenotomy of the superior rectus of the hyperphoric eye, including only its temporal fibers, so as to carry its plane of rotation farther toward the nose, and a like operation on the nasal fibers of the inferior rectus of the cataphoric eye, so as to carry its plane of rotation farther toward the temple. An equal effect should be attained by these two operations. If a case of this character should be asthenic, the inferior rectus of the hyperphoric eye should be so shortened as to carry its plane of rotation farther toward the temple, while the superior rectus of the cataphoric eye should be so shortened as to carry its plane of rotation farther toward the nose.

CYCLOPHORIA.

Cyclophoria is the tendency of the vertical axes of the eyes to lose parallelism with the median plane of the head. In the interest of binocular single vision and correct orientation this parallelism must be maintained by the oblique muscles, except in cases of oblique astigmatism. For this purpose there are four conjugate innervation brain-centers: (1) The sixth conjugate center sends an impulse to the two superior obliques to prevent divergence of the vertical axes when the point of view is in the extended median plane of the head, but below the extended horizontal plane; (2) the seventh conjugate center sends an impulse to the two inferior obliques to prevent convergence of the vertical axes when there is to be cardinal fixation above the horizontal plane; (3) the eighth conjugate center sends an impulse to the superior oblique of the right eye and inferior oblique of the left eye to prevent torsion when the point of fixation is obliquely up-and-to-the-right, or down-and-to-the-left; and (4) the ninth conjugate center sends an impulse to the superior oblique of the left eye and inferior oblique of the right eye to prevent torsion when the point of fixation is up-and-to-the-left, or down-and-to-the-right. Under the influence of one or another of these conjugate centers, the parallelism of the vertical axes of the eyes with the median plane of the head is maintained, regardless of the direction of the point of fixation. In a normal condition of all the extrinsic ocular muscles, the obliques accomplish this purpose with ease. Whenever conditions are such as to make it difficult for the obliques to maintain this parallelism, except when under an excessive nervous tension, there is cyclophoria.

When this condition was first described, by the writer, in the *Archives of Ophthalmology*, in its issue of January, 1891, the name given it was "insufficiency of the obliques," which was not inapt; for whatever may be the chief cause or causes of this error, the obliques are insufficient for the work of easily keeping the vertical axes of the eyes parallel with the median plane of the head. In 1893, in conformity with the terminology introduced by Stevens, the term "cyclophoria" was coined by G. H. Price, of Nashville, Tenn. Plus cyclophoria means that the vertical axes of the eyes have a tendency from the median plane of the head; minus cyclophoria is a tendency of these axes toward the median plane. For the same conditions Maddox uses the terms "plus torsion" and "minus torsion"; and Stevens, "plus declination" and "minus declination." Either of these terms would be as good as those coined by Price, except for the desirableness of uniformity in terminology.

While cyclophoria is most important as it pertains to the two eyes in their efforts to maintain binocular single vision, it is, nevertheless, a factor for disturbance in monocular vision. In order that the law of direction may not be interfered with, in vision with one eye, its vertical axis must always be parallel with the median plane of the head; and, necessarily, its transverse axis must always lie in the plane of the primary isogonal circle. Orientation alone compels this parallelism when there is but one eye.

There are two kinds of cyclophoria—viz., symmetrical and non-symmetrical. Symmetrical cyclophoria is either plus or minus for both eyes; non-symmetrical cyclophoria is plus for one eye and minus for the other. Rarely there may be a plus or minus cyclophoria for one eye, while the obliques of the other perform their work easily. Plus cyclophoria is by far more common than minus cyclophoria, the proportion being about 1 to 50.

Causes of cyclophoria. The cause may be wholly in the obliques. The nearer the attachment of an oblique muscle is to the equator, the greater is its torsioning power; while attachment of an oblique nearer the posterior pole of the eye gives it less torsioning power. Attachment of both inferior obliques nearer the equator than that of the superior obliques, would give a plus cyclophoria, the muscles themselves being normal in development. When the superior obliques are attached nearer the equator than are the inferior obliques, a minus cyclophoria would result. Granting that the attachments are correct, hyper-development of the inferior obliques, or subnormal development of the superior obliques would give a plus cyclophoria; while hyper-development of the superior obliques, or subnormal development of the inferior obliques would cause a minus cyclophoria. This presupposes that the innervations are normal.

Hyper-development of the seventh conjugate innervation center, or subnormal development of the sixth, would cause a plus cyclophoria; while hyper-development of the sixth or subnormal development of the seventh conjugate center, would cause a minus cyclophoria. This presupposes that the muscles themselves are normal in both structure and attachment. In either case the plus cyclophoria would be complicated by a double cataphoria.

A too high attachment of the interni or a too low attachment of the externi would cause a minus cyclophoria, while a too low attachment of the interni or a too high attachment of the externi would cause a plus cyclophoria. When there is a normal attachment of the interni, there can result from their action no cyclophoria.

The superior and inferior recti constitute the only remaining source

of symmetrical cyclophoria. When these muscles are normal in structure and attachment there can be no cyclophoria resulting from their action. A double hyperphoria due to hyper-development of the superior recti or subnormal development of the inferior recti, gives a minus cyclophoria; while hyper-developed inferior recti or subnormally developed superior recti, in causing double cataphoria, also cause plus cyclophoria.

Non-symmetrical cyclophoria is a tendency to parallel deviation of the vertical axes of the eyes, being plus for one eye and minus for the other. This tendency may be to the right or to the left. If this kind of tendency should become a turning, diplopia would not result, but there would be interference with the law of direction. Because of this interference the weaker obliques (superior of one eye and inferior of the other) are kept in a state of nervous tension, that they may keep the vertical axes of the eyes parallel with the median plane of the head. The corrective impulse may come from the eighth conjugate center when the tendency of the vertical axes is toward the right, and from the ninth center when the tendency is toward the left. When the tendency is toward the right, rotation of the eyes obliquely up and to the right, or down and to the left, is more difficult than rotation up and to the left, or down and to the right; and vice versa, when the tendency is toward the left.

The obliques may cause this condition. To do so the superior oblique of one eye must be too strong for its inferior oblique, or the former must be attached nearer the equator than the latter; while the inferior oblique of the other eye is either stronger than its superior oblique or is attached nearer the equator. In such a case there would be not only parallel cyclophoria, but there would be also a cataphoria of the one eye and a hyperphoria of the other. Parallel cyclophoria can be caused by the interni when one is attached in greater part above the transverse plane of its eye, while the other is attached in greater part below this plane. There would also result a hyperphoria of the one eye and a cataphoria of the other. Faulty attachment of the externi, the one too high and the other too low, would cause parallel cyclophoria. In such a case there would be a hyperphoria of one eye and a cataphoria of the other. When hyperphoria of one eye is caused by too strong superior rectus and cataphoria of the other is caused by a too powerful inferior rectus, parallel cyclophoria will also result, the tendency being to the right when there is left hyperphoria and to the left when there is right hyperphoria.

Tests. Cyclophoria was first discovered by the writer, in 1890, by means of a Maddox double prism which was being used for determin-

ing an imbalance of the lateral recti. The patient was asked if the middle candle was in a vertical line with the upper and lower candles. She stated that the lower candle was not directly under the upper one, although the axis of the double prism was vertical, or so judged by the eye of the operator. The axis of the prism had to be tilted 5° or more toward the temple before the patient claimed that the upper and lower candles were in a vertical line. This showed clearly that the vertical retinal meridian was inclined toward the temple and to a greater extent than Helmholtz had taught as normal. At once a line was drawn across a card and held before the patient. She saw two lines with the eye before which the double prism was held, and these lines were parallel. The other eye was then uncovered, when she saw a third line between the other two lines, but not parallel with them. The middle line was seen by the left eye, and it was seen inclined down to the right. Other cases were investigated, about twenty-five per cent. of them showing the same error found in the first patient, which was plus cyclophoria. The first publication was made in the *Archives of Ophthalmology*, Vol. XX, No. 1 (1891), page 105. This paper was gloomy in that it presented no prospect of either prevention or cure. From the time of the discovery of cyclophoria, in 1890, up to May, 1892, many cases had been found, but none of them had been treated; nor was it thought possible, up to this time, that any curative measure would ever be devised. On May 17, 1892, the thought of developing weak oblique muscles by exercising them with cylinders first presented itself. This thought was put into practice at once, and the results were gratifying. This led to the presentation of a second paper which was read before the Section of Ophthalmology of the American Medical Association at the Detroit meeting, in June, 1892.

Double prism. The double prism will always show cyclophoria when the test object is a horizontal line. The kind of cyclophoria—whether plus or minus—is easily ascertained in this way, but its quantity cannot be measured. Substituting a dot for the line, the error may be measured by revolving the double prism until the two dots seen through the prism are in a vertical line. The extent of inclination of the axis of the prism would be equal to the amount of the cyclophoria. In using the double prism for this measurement test of cyclophoria, the operator must be careful to have the axis of the prism vertical in the beginning and note its inclination at the end of the test. He need not be so careful to have the patient's head erect, for the result will be the same whether the head is erect or inclined. However, since tests of some of the eye muscles require that the head shall be erect, it is better to have it thus in all tests.

The cut used to illustrate the first paper is reproduced here, together with the descriptive text:

"Place a double prism, axis vertical, before one eye, the other for the moment being covered, and ask the patient to look at a horizontal line on a card held sixteen inches away. The effect of the double prism (each 6°) is to make the line appear to be two, each parallel with the other. The other eye is now uncovered, and a third line is seen between the other two, with which it should be perfectly parallel.

"While a change of the position of the axis of the double prism, from the vertical toward the horizontal, will alter the distance between the lines, their direction will be unchanged—hence, no loss of parallelism. This fact admits of a little carelessness in the placing of the prism in the trial frames, though the axis should be vertical, so as to give the maximum distance between the two extreme lines.

Fig. 35.

Fig. 36

Fig. 37.

Fig. 38

Fig 39.

"If there is a want of harmony on the part of the oblique muscles, this test will show it at once in a want of parallelism of the middle line with the two other lines, the right end of the middle line pointing toward the bottom line and the left end toward the top line, or vice versa, depending on the nature of the individual case.

"Consider the eye before which no prism is held as the one under test. With the double prism before the right eye, the patient is asked about the position and the direction of the middle line. It may be nearer the bottom line, thus showing left hyperphoria; or, again, it may extend farther to the right than the other two, and not so far to the left, thus showing exophoria; or vice versa, showing esophoria.

"If the right ends of the middle and bottom lines converge while the left ends diverge, the superior oblique of the left eye is at once shown to be in a state of underaction. Fig. 35 represents such a test

of the left eye; Fig. 36 shows a test of the left eye when the inferior oblique is the too weak muscle; Fig. 37 represents a test of the right eye, the loss of the parallelism between the lines being due to under-action of its superior oblique; Fig. 38 the same condition of the inferior oblique of the right eye; Fig. 39 represents a test of both eyes when there is perfect equilibrium of the oblique muscles.''

The single prism. The single prism of 6°, with its base up or down before one eye, the test object being a horizontal line on a blackboard at twenty feet distance, or on a card at the reading distance, will double the line. If the two are not parallel, there is cyclophoria. The false line inclined toward the opposite side shows plus cyclophoria; the same line inclined toward the corresponding side shows minus cyclophoria. The quantity of the cyclophoria cannot be measured with the single prism by substituting a dot for the line, as in the use of the double prism.

The Risley prism. The rotary prism of the monocular phorometer can easily show the existence of cyclophoria, or its absence. As with other prisms, the test object is a line. The rotary prism is adjusted for taking sub-duction and super-duction. When it is rotated up or down beyond the point of possible fusion, the line becomes double. If they converge at one end or the other, there is cyclophoria—plus, if the false line is inclined toward the opposite side; minus, if it is inclined toward the same side. Rotating the prism slowly so as to carry the index toward zero, the two lines fuse, first at one end and then quickly fuse throughout. The rotary prism cannot possibly measure the amount of cyclophoria.

The clinoscope. The Stevens clinoscope both detects and measures any form of cyclophoria. The opaque discs with a single pin, with the head in the center, drawn on each, should be placed so that the point may be up for one eye and down for the other. Each pin should be vertical, and the instrument should be so adjusted as to allow easy fusion of the heads of the pins. When the two discs appear as one, the two pins should be the vertical diameter of the fused disc. If the one pin is a radius pointing obliquely in one direction and the other is a radius pointing obliquely in the other direction (one toward the right and the other toward the left, making an oblique diameter), there is plus cyclophoria of one eye and minus cyclophoria of the other. If the upper pin is seen by the left eye and the lower pin is seen by the right eye, the two pins pointing to the right would show plus cyclophoria; while minus cyclophoria would be shown by the two pins pointing to the left. If the top pin is vertical and the bottom one points to the right, there is plus cyclophoria of the right eye alone;

or, if the bottom pin points to the left, while the top one is vertical, there is minus cyclophoria of the right eye alone. When both pins are oblique, the tubes to which the discs are fastened should be revolved until the two pins are vertical, forming apparently the vertical diameter of the fused disc. The index connected with each tube will point to the mark on the scale indicating the quantity of the error for each eye.

The errors of the obliques could be detected with equal ease, and measured with as much exactness, if the discs were placed so that the pins would be horizontal, the one seen by the left eye pointing to the left and the one seen by the right eye pointing to the right, their heads being fused. To eyes whose oblique muscles are perfectly balanced the pins would appear as the horizontal diameter of the fused disc. If the two pins appear to point downward, there is minus cyclophoria; if they appear to point upward, there is plus cyclophoria. If the left pin points downward, while the right pin points upward, there is minus cyclophoria of the left eye and plus cyclophoria of the right eye (parallel cyclophoria). In either case, rotation of the two tubes until the pins appear to be horizontal, constituting the apparent horizontal diameter of the fused disc, measures the error.

The cyclophorometer. The cyclophorometer will also detect and measure both symmetrical and non-symmetrical cyclophoria. The instrument must be perfectly level, and the index of each triple rod must stand at zero. The 5° prism, base up, must be placed in the slot behind one rod, while a red glass may be put in the slot behind the other rod. The test object must be a candle, gas jet, or small electric light. The red streak above and the yellow streak below must be made even by the regulating screw. To perfectly balanced eye these streaks would appear parallel. If the red streak is seen by the right eye and the two converge at the left, there is plus cyclophoria; if they converge at the right, there is minus cyclophoria. If they appear parallel, but inclined, there is plus cyclophoria of one eye and minus cyclophoria of the other. If one is horizontal and the other is inclined, there is cyclophoria of one eye alone. The disc containing the rods should be turned until both streaks are perfectly horizontal and, therefore, parallel. If the index of each stands in the lower nasal arc when the streaks are made to appear horizontal, there is plus cyclophoria; and if they stand in the lower temporal arcs, there is minus cyclophoria. The quantity of the error in each eye is measured by the arc traversed by the index and is shown on the scale. If only one rod is turned until the two streaks become parallel, but not horizontal, the

quantity marked by the index is the sum of the cyclophoria of the two eyes. If there is parallel cyclophoria, the quantity is shown by revolving the two rods until the two streaks are horizontal.

Cyclo-duction. Cyclo-duction can be taken either with the clinoscope or the cyclophorometer. If the clinoscope is used, the discs, with a diameter drawn across each, should be attached. They can be set with the diameters either vertical or horizontal. When vertical, revolving the tubes so that the lines shall deviate from each other above will put into action the inferior obliques. If only one tube is revolved, only one inferior oblique is called into action, while revolving both tubes will call into action both inferior obliques. The normal duction power of the obliques is not so well known as that of the recti. It is somewhere between 7° and 14° for one, and 22° or less, for both inferior obliques.

Revolving the tubes so that the lines converge above puts the superior obliques to the strength test. If only one tube is revolved, only one superior oblique is called on for a fusion effort; but if both are revolved, both eyes must be cyclo-ducted by the two superior obliques. The fusion power of the superior obliques is less than that of the inferior obliques, but how much less normally is not known. In plus cyclophoria, minus cyclo-duction is diminished and plus cyclo-duction is increased; while in minus cyclophoria, plus cyclo-duction is less and minus cyclo-duction is greater. In taking either minus or plus cyclo-duction the revolution of the cylinders must be stopped the moment the lines begin to be seen separately. The index will point to the number indicating the extent of the fusion rotation.

Placing the discs so that the two diameters shall be horizontal, both plus and minus cyclo-duction can be taken as easily and accurately as, if not more accurately than, when these lines are vertical. Rotating the tubes so that these lines are made to point downward at their outer ends will call into fusion activity the two inferior obliques, while rotating them so that they shall point upward will excite into fusion activity the superior obliques.

When the cyclophorometer is used for measuring the fusion power of the obliques, the instrument should be adjusted as for testing for cyclophoria. As soon as the rods are so rotated that the one streak of light is directly under the other, both the displacing prism and the red glass should be removed. At once the two lines would be fused into one horizontal line. Revolving one rod so that the index shall move in the lower nasal arc puts to the test the inferior oblique of that eye; revolving both rods so that each index shall be in the lower nasal arc puts both inferior obliques to the test. When the two streaks

of light are well defined and exactly alike as to width and color, the plus cyclo-duction should be as great with this instrument as with the clinoscope.

Revolving the rods so that the index of each shall move in the lower temporal arc, excites into fusion activity both superior obliques. If one alone is to be tested, only the one rod should be revolved, the other being allowed to stand at zero. Thus plus and minus cyclo-duction should be taken in all cases of cyclophoria; and even when there is no cyclophoria, these should be taken and noted, so that a standard may be attained.

Cyclo-version is impossible, since voluntary rotation of the eyes around the visual axes cannot be accomplished.

In the study of the causes of cyclophoria, all of the complications have been considered. Under the head "Treatment" they will be referred to again, since the treatment, whether surgical or otherwise, is largely determined by these complications.

Symptoms. Any one or several of the symptoms mentioned in the study of heterophoria may result from cyclophoria. Vertigo and nausea are more commonly found associated with cyclophoria than with any other form of heterophoria. As already shown in the study of hyperphoria and cataphoria, it is plus cyclophoria that causes the tilting of the head toward the cataphoric side, and minus cyclophoria that causes the tilting of the head toward the hyperphoric side.

Symmetrical plus cyclophoria associated with double hyperphoria causes high-headedness, for the reason that the superior obliques can more easily counteract a plus cyclophoria when the visual axes are depressed below the extended horizontal plane of the head. Symmetrical minus cyclophoria with a double cataphoria causes the patient to carry his head thrown forward, giving a downcast appearance, because in this position the inferior oblique can counteract more easily the minus cyclophoria.

Treatment of cyclophoria. Rest cylinders, exercise cylinders, and operations on the recti constitute the means for curing cyclophoria. When cyclophoria was discovered, in 1890, a cure was thought to be impossible. In 1892 the first case was treated with exercise cylinders.

The germ of the idea of operating on the recti, so as to help weak obliques, is embodied in language found in the *Ophthalmic Record*, in its issue of March, 1893. These are the words: "In doing advancement operations on the recti muscles, one of the chief dangers is turning the eyeball on its antero-posterior diameter so as to throw unbearable strain on either the superior or inferior oblique muscles." At once it should have occurred to the author of the quotation just

made that, naturally, the recti might be so attached as to do the very same thing—that is, develop a cyclophoria.

While in attendance on the first Pan-American Medical Congress, in Washington (1893), Swan M. Burnett suggested to the author that the superior and inferior recti might have such a scleral attachment as to throw an undue amount of strain on the obliques. On hearing this statement the author made this suggestion: "If you are correct, some cases of insufficiency of the obliques can be cured by dividing the offending fibers of the inferior (or superior) recti." This was published in the first edition of "*New Truths in Ophthalmology*" (1893), page 41.

Rest cylinders. These can be given for either plus or minus cyclophoria, even when there is no astigmatism to be corrected. The objection to this practice is that, while they give rest to the weak obliques, they, at the same time, make images on the retina less distinct. It is the distorting, or it would probably be better to say "the displacing," of images that gives rest to the weaker obliques. It is no longer denied that, in astigmatism, all lines not parallel with one or the other of the two principal meridians have their images displaced toward the meridian of greatest curvature. To fuse such displaced images (displaced in opposite directions) there must be compensating cyclotropia, just as there must be compensating esotropia in order to fuse images that are thrown to the temporal side of the maculas by prisms with their bases out. The law of corresponding retinal points, which is supreme, compels the cyclotropia of oblique astigmatism, notwithstanding it must interfere with the law of direction, in that the vertical axes of the eyes are made either to converge or diverge above. Artificial oblique astigmatism produces the same changes in images of vertical and horizontal lines as does natural oblique astigmatism. When there is plus cyclophoria, natural oblique astigmatism of 1 to 2 D., with the meridians of greatest curvature converging above, is often attended by more comfort, because of the rest it gives to the superior obliques, than the correcting cylinders would give; for when the correction is given, the image of every line in space is in a plane with the line itself, and to fuse these images the weak superior obliques must parallel the vertical axes of the eyes with the median plane of the head. To do this their normal tonicity must be supplemented by a nervous tension which they poorly bear. What natural astigmatism will do, artifical astigmatism will accomplish. Only weak cylinders should be used for non-astigmatics, with the view of resting weak oblique muscles. More than 1 D., whether the axis be made to incline little or much, would blur objects unnecessarily. Cylinders of .50 D.

are usually strong enough, especially when their axes are made to incline far toward maximum points, in the proper arcs. For plus cyclophoria the arc of distortion for plus cylinders is the lower nasal arc; for minus cylinders, the lower temporal arc. The maximum distortion by the cylinder is accomplished when its axis stands at 45° from the vertical. For minus cyclophoria the arc of distortion for plus cylinders is the lower temporal arc; for minus cylinders, the lower nasal arc. For non-astigmatics each arc of distortion is 90°, the distortion or displacement gradually increasing as the axis of the cylinder is carried up to the midway point (45°) of the arc, and then gradually grows less as the axis is carried on toward the horizontal, at which point there can be no distortion. The most useful cylinder is a plus .50 D. when there is esophoria as well as cyclophoria, or a minus .50 D. when there are exophoria and cyclophoria. The quantity of the cyclophoria determines the location of the axes of the cylinders, but in no case need they be placed farther from the vertical than 45°, for this is the point where they accomplish the maximum distortion, thereby securing, for the weak obliques, the greatest amount of rest. Given a case of plus cyclophoria that is also esophoric, but non-astigmatic, to obtain rest for the weak superior obliques a plus .50 D. cylinder should be given for each eye, placing the axis of the right cylinder at some point between 90° and 135°, or at the latter, while placing the axis of the left cylinder at some point between 90° and 45° or at the latter. These cylinders will give additional comfort to nearly all cases of this kind.

It is better, however, to cure these cases either by exercising the weak superior obliques or by operating on the interni.

If there is a hyperphoria of one eye and a cataphoria of the other, as well as plus cyclophoria, the rest cylinder should be applied only to the cataphoric eye. The inferior oblique, in torting this eye out for fusing images with the fellow eye, would also elevate the eye, counteracting the cataphoria For a like reason the rest cylinder should be applied only to the hyperphoric eye for the relief of minus cyclophoria. But it would be better practice to cure the plus cyclophoria by a marginal tenotomy (on nasal side) of the superior rectus of the hyperphoric eye, or by exercising both superior obliques.

Correcting cylinders. Cylinders given for the correction of astigmatism, oblique and non-oblique, may be so placed as to give rest to weak superior obliques when there is plus cyclophoria, or to weak inferior obliques when there is minus cyclophoria. If the astigmatism is vertical and hyperopic, the arc of distortion by the plus cylinder for the superior oblique is 90°, and that for the inferior oblique is also

90°, their sum being 180°; if the astigmatism is oblique, the meridian of greatest curvature of the right eye being at 60° and that of the left eye at 120°, the arc of distortion by the correcting cylinders for the superior obliques will be 30°, and that of the inferior obliques will be 150°, their sum being 180°. If the meridian of greatest curvature of the right eye is 45°, and of the left eye at 135°, there is no arc of distortion for the superior obliques, but the arc of distortion for the inferior obliques is 180.° The center of the arc of distortion by plus cylinders for the superior obliques is at 45° in the lower temporal arcs, and for the inferior obliques is at 45° in the lower nasal arcs. This is reversed in the use of minus cylinders. This has been elucidated further in the section on **Oblique astigmatism.**

From what has just been said, it will be understood that, when plus cylinders are used for correcting astigmatic errors, their axes must be turned from the point indicated by the astigmatism toward the center of the lower nasal arc for the relief of weak superior obliques in plus cyclophoria, and toward the center of the lower temporal arc for the relief of weak inferior obliques in minus cyclophoria. The extent of the displacement of the axes depends both on the strength of the cylinders and the quantity of the cyclophoria. Rarely should this displacement be more than 5° if the cylinders are plus 1 D., or stronger; but weaker cylinders may be revolved much farther.

Culbertson, in his paper on "Binocular Astigmatism" (1888), displaced the axes of his cylinders with the view of correcting the appearance of slanting floors, leaning walls, and distorted figures, without any reference at all to the oblique muscles; but, after all, the benefit derived was from giving rest to the weak obliques. In vertical astigmatism, the cylinders do not cause the floor to slant or the wall to lean; and yet it is just as essential to displace the axes of the correcting cylinders in the proper arcs, when there is cyclophoria, as it is to displace the axes of cylinders correcting oblique astigmatism.

In 1894, Nettleship, and probably others on the staff of the Royal Ophthalmic Hospital, London, was in the habit of directing that the axes of cylinders should be placed at 90° or 180°, when accurate measurements showed that the two principal meridians were removed only a few degrees from these points. When asked why he did this, he said that some patients derived more comfort from the displaced cylinders. There was then present a female patient who could not wear her cylinders thus displaced. Inquiry elicited the fact that she had been given plus cylinders—axes 90°—for each eye, when the record showed that the meridian of greatest curvature of the right eye was at 100°, and of the left eye at 80°. These cylinders were dis-

placed in the arcs of distortion for the superior obliques, which were evidently too weak to bear the consequent over-action. In that case it would have been better to have displaced these axes farther from the vertical instead of to it.

Better than displacing the axes of correcting cylinders, so that they may give rest to the weak oblique muscles, is to make these muscles strong by exercise, or else correct the cyclophoria by operating on one or more of the recti.

Exercise of the obliques. The Stevens clinoscope can be used for exercising the obliques; but this would require the time of the surgeon or his assistant. The discs used should be those marked with the diameter, and not with the radius, unless the two radii should be made both to point in the same direction. The former would be better. The discs could be placed with the diameters either vertical or horizontal. Revolving the two tubes, so that the indicators would point toward each other, would call into action the superior oblique muscles; but when made to diverge from each other, the inferior obliques would be called into action. Reversing the revolution, in either case, so that each indicator would stand at zero, would bring the obliques into the state of rest. In this way rhythmic exercise of the obliques may be accomplished, and a plus or minus cyclophoria cured.

The cyclophorometer likewise can be used for exercising the obliques; but this too would require the time of the surgeon or his assistant. It should be adjusted for easy fusion of the two streaks of light, as if for the purpose of taking the cyclo-duction. Revolving the two rods, so that the indicators would move in the lower temporal arcs, would call into action the superior obliques; and revolving them so that the indicators would move in the lower nasal arcs would call into action the inferior obliques. In either case, reversing the motion, so that the indicators may be made to stand at zero, would cause relaxation of these muscles. The revolutions could be repeated so as to cause rhythmic exercise of the obliques, and thus cure cyclophoria. The displacement should not be more than half that for cyclo-duction in either of these methods.

Whether the one or the other of these means should be used, the exercise should not cause fatigue, and in no case should it be continued longer than ten minutes. It need not be repeated oftener than once a day.

Exercise cylinders. The only means for exercising the oblique muscles, which a patient can use without assistance, consists of a pair of cylinders set in circular rims, so that they may be turned in the proper directions for displacing a horizontal line so as to call into

action the proper muscles in the treatment of cyclophoria. The frames for this purpose are made of German silver, with circular rims. These rims are deeply grooved to allow a free rotation of the lenses. The rims are marked at points fifteen degrees apart, from 90° to 45°, in either the lower temporal or lower nasal quadrant, depending on the pair of muscles affected. The cylinders used are usually plus 1.50 D., and the axis of each is plainly marked, as shown in the cut. The frames are not marked, nor are the cylinders cut, except by the oculist's order.

Fig. 40 represents a pair of exercise cylinders ordered for a patient's own use, whose superior obliques are insufficient. The rims, as shown, are marked in the lower temporal quadrant. at four points fifteen degrees apart. The cylinders, whose axes are distinctly marked, can

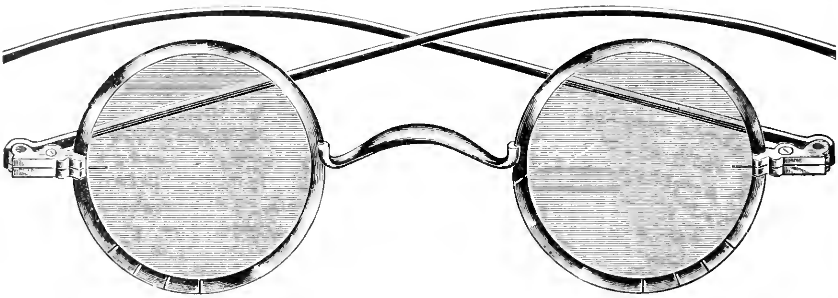


Fig. 40.

be readily revolved. The patient is directed to place the mark on each lens at the second notch. Placing them now before her eyes, she is instructed to look at a horizontal line eight or ten feet distant for three seconds, then without them for three seconds, then again with them for three seconds, and so on for five minutes. Now the two lenses are to be revolved so that their marks point to the No. 2 notch on the rim. The line is now looked at, as above, for three minutes. Now the last change in position of lenses is made by revolving their marks to notch No. 3, the point of maximum action. The patient again looks at the line, as above, for two minutes, which ends the exercise for that day—ten minutes in all.

The marking of the rims must be in the lower nasal quadrant when the patient has insufficiency of the inferior obliques, the exercise lenses to be plus cylinders. The revolution is made in the direction of the notching in both classes of cases. The points at which to stop and the time to look at the line are the same for both plus and minus cyclophoria. The exercise is accomplished by raising and lowering

the frames at intervals of three seconds. This exercise should not be carried to the point of fatigue, nor should it be continued longer than ten minutes.

Once a day is sufficiently often to resort to the exercise. The lightest work is done when the axes of the cylinders stand at the first notch, and it is continued longest; while the heaviest work is demanded when the axes stand at the highest notch, and for this reason it is continued the shortest time.

It is clear that these cylinders are intended for the production of artificial oblique astigmatism, which must effect the same changes in images as are found in natural oblique astigmatism. Plus cylinders revolved as shown in Fig. 40 make the meridians of greatest refraction diverge from each other above; for the axes of the cylinders, representing the meridians of least curvature, converge above. These cylinders make horizontal lines dip toward the opposite side. To keep the images fused, the superior obliques must tort the eyes in. Raising the frames, the images of the horizontal line are no longer oblique, hence the muscles that torted the eyes in must now relax.

If minus cylinders are used, their axes should be placed in the nasal arcs of the frames for exercising the superior obliques, and in the temporal arcs for exercising the inferior obliques. The axis of the minus cylinder represents the meridian of most refraction, hence the need for rotating it in a direction different from that for the plus cylinder.

The cylinders, whether plus or minus, may be of any strength from .50 D. to 1.50 D. Rarely should the cylinder be stronger than 1.50 D.

These cylinders were first used for exercising the obliques on May 17, 1892. The first case was cured of a plus cyclophoria after a reasonably short time of faithful exercise, and remains cured to this day, May 1, 1916.

Operative treatment. A plus cyclophoria unaccompanied by any other form of imbalance, if high in degree and unrelievable by non-surgical means, should be treated by operating on both superior recti, dividing only their nasal fibers; or by operating on both inferior recti, shortening or advancing their nasal fibers. In either case, the cyclophoria would be cured and double cataphoria would be developed.

A plus cyclophoria complicated by a double hyperphoria should be relieved by cutting the nasal fibers of both superior recti, which should result in a cure of both conditions.

A plus cyclophoria complicated by double cataphoria should be treated by dividing the temporal fibers of both inferior recti.

A plus cyclophoria complicated by right hyperphoria and left cata-

phoria calls for a division of the nasal fibers of the right superior rectus and the temporal fibers of the left inferior rectus. These operations should cure both conditions.

A plus cyclophoria complicated by sthenic esophoria should be treated by dividing the lower fibers of both interni; but when the esophoria is asthenic, the operation should be a shortening or advancement of the lower fibers of both externi.

A plus cyclophoria complicated by sthenic exophoria calls for a division of the upper fibers of both externi; but when the exophoria is asthenic, the upper fibers of both interni either should be shortened or advanced.

A plus cyclophoria complicated by sthenic esophoria, right hyperphoria, and left cataphoria, demands that the lower fiber of the left internus should be divided, so as both to elevate the cataphoric eye and tort it in. If there remains some of both the plus cyclophoria and right hyperphoria, the nasal fibers of the right superior rectus should be cut.

A plus cyclophoria complicated by sthenic exophoria, right hyperphoria, and left cataphoria, calls for a division of the upper fibers of the right externus, so as both to depress the hyperphoric eye and tort it in. Should there remain some of the plus cyclophoria and left cataphoria, the temporal fibers of the left inferior rectus should be severed.

Very rarely there is minus cyclophoria, either complicated or uncomplicated, that calls for surgical treatment. It only must be remembered that the part of a muscle cut, shortened, or advanced for plus cyclophoria must remain intact when the condition is minus cyclophoria; and that the margins left intact in the treatment of plus cyclophoria must be either divided, shortened, or advanced for minus cyclophoria.

Plus cyclophoria of the right eye and minus cyclophoria of the left eye (parallel cyclophoria), if uncomplicated, calls for a division of the nasal fibers of the right superior rectus and the temporal fibers of the left superior rectus. While these operations would parallel the vertical axes of the eyes with the median plane of the head, they would develop a double cataphoria. A case of this kind, complicated by right hyperphoria and left cataphoria, calls for a division of the nasal fibers of the right superior rectus and the nasal fibers of the left inferior rectus.

The obliques themselves should never be subjected to an operation for cyclophoria; but, as will be shown further on, the inferior oblique may be divided when there is plus cyclotropia.

In the treatment of heterophoric conditions by any method outlined

in this section, the aim is to relieve the basal or fusion brain-centers from abnormal work, by giving equal tonicity to the two muscles of any pair—the establishment of orthophoria.

To withhold the treatment indicated in any given case of heterophoria is unjust to the patient and will be hurtful to the practitioner. The day has forever passed when an oculist can securely boast of ignorance of heterophorias, on his own part, and, in turn, speak disparagingly of others who claim to know. Confession of ignorance on his own part disqualifies one for passing unfavorable judgment on others who, by means of hard study and close observation, have a right to claim that they know.

HETEROTROPIA.

Heterotropia is a turning of one or both visual axes, or of one or both vertical axes, either in the interest of binocular single vision; that is, in obedience to the law of corresponding retinal points; or it is a turning in spite of the demands of this supreme law. In the former there is binocular single vision, but at the expense of the law of visible direction; in the latter there is only monocular vision, without infringement of the law of direction. The former is best named *compensating heterotropia:* while the latter should be called *comitant heterotropia.* There are as many kinds of heterotropia as there are varieties of heterophoria—the former is an actual turning, while the latter is only a tendency towards turning, the actual turning being prevented by the activity of the proper fusion centers. When the weaker muscle of a pair no longer responds to the impulse from its fusion center, the stronger muscle causes the eye to turn into an abnormal or unharmonious position. Without the previous existence of heterophoria there could be no comitant heterotropia. Non-comitant heterotropia has paralysis or paresis of one or more ocular muscles for its cause, and it occurs independently of any pre-existing muscle state.

The appearance of eyes whose muscles fail to coördinate them, rendering binocular single vision impossible, has been designated by the terms "squint," "strabismus," and "cross-eyes," by both ancient and modern writers. It may be long before these terms can be entirely eliminated, although there is now no good reason for retaining them. "Heterotropia," a term introduced by Stevens, carries its own meaning with it, the plain English of which is a "wrong turning." This term should be preferred, not only because of its simplicity, but also because it is in conformity with the now usually accepted term, "heterophoria," as applied to the muscles whose relationship to each other is such as to render it difficult for them to so relate the eyes as

to make binocular vision possible. "Heterotropia" is a generic term, and includes all forms of deviation of the visual axes and the vertical axes of the eyes; "esotropia" means that there is a deviation of the visual axes inward, so that they cross each other between the observer and the point of observation; "exotropia" means that there is an outward deviation of the visual axes, so that they either cross beyond the point of view or become parallel, or even become divergent; "hypertropia" means that one visual axis is raised above the other, while "catatropia" means that one visual axis is turned below the other; "cyclotropia" means that the vertical axes of the eyes are not kept parallel with the median plane of the head, either diverging from it above (plus cyclotropia) or converging toward it above (minus cyclotropia). One form of heterotropia may be complicated by one or more of the other forms.

As taught earlier in this section, binocular single vision is possible only when the superior and inferior recti muscles keep the two visual axes in the plane of the primary isogonal circle; when the internal and external recti so control these axes, in that plane, as to make them intersect at the point of view on that circle; and when the superior and inferior obliques parallel the vertical axes of the eyes with the median plane of the head, or what is the same thing, keep the horizontal retinal meridians in the plane containing the visual axes. These muscles accomplish this work in obedience to the unalterable law of corresponding retinal points. Disobedience on the part of these muscles develops diplopia, for the reason that the two images of the one object cannot fall on corresponding retinal points. That objects are not always seen double by persons who have any form of heterotropia can be due to nothing else than mental suppression of one image—the one in the misplaced eye.

Before entering minutely into the study of heterotropia, it will be interesting to review, briefly, its history. That the condition has existed in every generation from the beginning of the human family, can hardly be doubted. What it was interpreted to mean in very ancient times cannot now be known. Hippocrates wrote of the deformity as a thing of inheritance, but sometimes resulting from disease. From the time of his writing, on down through the centuries, there is no evidence of any careful or scientific study of heterotropia until in the second quarter of the nineteenth century. About this time Stromeyer announced that strabismus was due to abnormal contractions of the eye muscles, and that it might be cured by tenotomies. He performed experimental tenotomies, on the dead subject, to his satisfaction. One year later, in 1839, Dieffenbach

operated on his first case of internal squint, dividing the tendon of the internal rectus close to its attachment to the sclera. He thus continued to operate through a lengthy series of cases. Other German surgeons, and surgeons in France and England, began at once to accept the teaching of Stromeyer and to adopt the practice of Dieffenbach. After the French Academy of Sciences had awarded its prize of six thousand francs—half to Stromeyer for conceiving the operation and demonstrating it on the dead subject, and half to Dieffenbach for having first operated on the living subject by cutting the tendon of the muscle close to its attachment to the sclera—Dieffenbach himself led in the bad practice of cutting the tendon farther back. He reasoned that the farther from the insertion the cut was made, the greater would be the effect, and by this reasoning he was induced, in severe cases, to make the cut through the muscle structure itself. So disastrous were these myotomies, or tenotomies far behind the insertions of the tendons, that the operation for strabismus began to fall into disrepute. It required the master mind of Graefe to check the tide of professional feeling against tenotomies of the recti muscles. His voice called operators back to the original operation of Dieffenbach, after which external squints were less frequently found as a result of operations for internal squint, and once more the operation came into favor. Graefe even went farther in the direction of safety than a simple return to the Dieffenbach original tenotomy, in that he advised partial tenotomies in the slighter cases. He even made marginal tenotomies, but apparently these were done empirically; at any rate, he did not give any reason for doing these marginal operations, other than that the uncut fibers would prevent the muscle from retracting too far. If done empirically, while some of them may have been helpful, others must have been hurtful, because of the wrong kind of torsioning resulting. It appears that Graefe abandoned marginal tenotomies, possibly because of the unfortunate torsional results that followed in many of his cases. That there is scientific—and, therefore, sound—basis for marginal tenotomies has already been shown and will be set forth again, in the proper place, in this study. It would also appear that Graefe ceased to do even central partial tenotomies; for, in conversation with Knapp, who was telling him of these operations which, thus early in his professional career, he was doing, he said, "You will not do that long." (See Norris and Oliver, Vol. III, page 877.) Thus indicating that he himself had already abandoned the practice of partial tenotomies. Yet it will be shown in this section that partial, and not complete, tenotomies only should be done, even in the higher degrees of heterotropia.

As was natural, soon after Dieffenbach's tenotomy operation on the contracted muscle was introduced, advancement of the relaxed muscle was suggested and practiced by Querin. The author has been unable to learn the exact method he employed, but it must have been very crude and unsatisfactory. A. von Graefe's improvement of Querin's operation is worthy of mention only as a curiosity. The only connection that the advancing thread had with the eye was the loop which he passed through the end of the severed tendon; for the two ends of the thread were carried across the cornea and anchored by adhesive plaster to the nose, if the muscle were the externus, and to the temple, if it were the internus to be advanced. The threads in contact with the cornea occasionally excited suppuration of that structure, and for this reason the operation was abandoned.

The elder Critchett, in 1862, at the Heidelberg Congress, made public his "method of advancement by stitching the tendon forward." This operation as described by Knapp is attended by unnecessary traumatism, and is not comparable, in simplicity and ease of execution, with the advancement operation now described in most books. The Critchett operation was adopted at once by Graefe, who was glad to substitute it for his own method. It seems not to have been intended by Critchett that this operation should supplant the operation of tenotomy for the cure of heterotropia, but that it should act only as an aid to the tenotomy.

Since 1878 Landolt has been an earnest advocate of advancement of the relaxed muscle, as against tenotomy of the contracted muscle, in all cases of heterotropia, and as the years have gone by his advocacy of advancement has grown stronger. Except for the greater ease with which a tenotomy is done, as contrasted with the advancement of a muscle, Landolt's voice would have been heard, and, to a greater extent, would have been heeded. But, strange to say, while Landolt has been opposing with all his might the cutting of the tendons of the ocular muscles, the tenotomists have found, or think they have found, the check ligaments of the recti muscles; and some of them, not content with completely severing the tendon, have dared to reach back with the scissors and cut these checks. That there are connective tissue fibers that extend from these muscles to the walls of the orbit cannot be denied, but they must be concerned more in firmly fixing the bed of fat through which the muscles pass, than with the action of the muscles, by either hindering or helping them. The dissection accomplished in cutting these ligaments can but allow a greater retraction of the divided tendon, which often proved to be too much even before the check ligaments were known to exist.

The only important suggestion in connection with complete tenotomies, since Graefe called operators back to the insertion of the tendon, has come from Panas; but even this suggestion does not redeem the operation of complete tenotomy from the condemnation laid upon it by Landolt. Panas stretches the muscle before severing its tendon. The stretching of the muscle necessarily results in a state of paresis for the time being, and it is probable that it takes days for the recovery to be effected. A paretic muscle, when cut, is not in a condition to retract far, hence adhesive inflammation has the opportunity to reattach the cut end of the tendon to the sclera only a little way behind the line of its original attachment. Panas' operation is the only safe complete tenotomy that can be done, but it is doubtful if it should ever be done. Words cannot be made strong enough to condemn a complete tenotomy associated with a cutting of the check ligaments. After any complete tenotomy, except the one suggested by Panas, the operator is exceedingly fortunate if, in a few months, he does not find a condition opposite that for which he operated. Even in Panas' operation the risk of limiting the verting power of the muscle is too great; and occasionally, in spite of the paresis caused by the stretching, the muscle will retract too far and an external squint will replace the former internal squint, or vice versa.

One of the strange things connected with the study of the ocular muscles, soon after Dieffenbach did his first operation, was the conclusion that the inferior oblique was an advertor of the eye. Certainly its origin, course, and insertion gave no foundation for such a conclusion. Lucas, in his little book on "*The Cure of Strabismus,*" published in 1840, says, on page 8: "The action of the inferior oblique is to direct the eye upward and inward." That the above reference to the inferior oblique could not have been a typographical error is abundantly shown in other parts of the book. On page 15 the following sentence occurs: "When either eye is drawn outward by the action of the external rectus muscle, the other is directed inward by the action of the inner rectus and inferior oblique muscles."

That the inferior obliques, without being advertors, may cause a condition that becomes an important complication of esotropia, will be shown farther on.

It is not uninteresting to study the work of a quack, John Taylor, who flourished in the first half of the eighteenth century, at least one hundred years before Stromeyer and Dieffenbach. He evidently found the secret of some cases of squint, and it is just as evident that his secret was kept by him and died with him. He wrote a pamphlet, entitled "*De Vera Causa Strabismi,*" which was published in 1738,

in which, it is said, he exploited his cures without exposing his method of operating. In traveling from city to city on the continent of Europe, distributing his pamphlet as a means of advertising, he styled himself as "Oculist to George II., of England," whom he probably had never seen; and when it suited him better, he claimed to be oculist to the Pope.

Taylor was a man of some penetration; but he must have been a man too full of self-interest to give to science and progress the benefit of his insight. He lost his opportunity to build for himself a monument that would have been to his enduring credit, by burying within himself the knowledge on which he based his practice of straightening cross-eyes. He seems not only to have been an oculist, but a general surgeon as well, for he carried about with him a dazzling display of instruments. His methods of secrecy and his disposition toward self-display must have disgusted surgeons of that time, so that they avoided him, just as honorable medical men of today feel disgraced when found in company with a quack. It appears, however, that LeCat either witnessed an operation or that he had an opportunity to question Taylor, for he says: * "I availed myself of the freedom which he accorded to me to inquire the motive for an operation which appeared to me to be absolutely useless, not to say dangerous. He replied that an eye only squinted because the equilibrium between its muscles was destroyed, and that to reestablish this equilibrium it was only necessary to weaken the muscle which dominated the others, and this is what he did in cutting one of the nerve filaments which was distributed to this too powerful muscle."

Heuerman, in 1756, wrote: "Taylor has also proposed to cure squinting by the division of the tendon of the superior oblique muscle of the eye." Another writer says that Taylor passed a silk thread through a fold of conjunctiva at the lower-inner part of the globe, and, drawing this fold forward by means of his loop of thread, cut it with a pair of scissors. The location of this conjunctival cut makes it appear possible that, through it, he passed his scissors with the point of one blade in contact with the orbital floor, and sufficiently far backward to include the inferior oblique muscle, which he may have divided by closing the blades of the scissors; or through the opening he may have passed, in a skillful way, one blade of the scissors between the sclera and the tendon of the internus while keeping the other blade between the conjunctiva and the tendon, and thus effected the division of this tendon.

* See Stevens' address before the Ophthalmological Association as published in *Annals of Ophthalmology*, Vol. VIII., No. 2.

Taylor must have had some cures, whatever may have been the nature of his operation. Simply sealing with plaster the eye not operated upon, for a few days, could not have effected a cure, unaided. There is no evidence of the existence of a nerve fiber far forward giving to the internus a part of its power; hence it is reasonable to conclude that he purposely made a misstatement when he told LeCat that his operation was a division of such a fiber. It is very unlikely that any case of internal squint ever had, as an etiological factor, a too strong superior oblique; hence it is not probable that Taylor ever divided this muscle. That a too strong inferior oblique may be an indirect factor in the production of a small per cent. of cases of internal squint will be shown farther on; hence it is not unreasonable to suppose that he may have divided this muscle in some of his operations. To have done so when this muscle elevated the eye and torted it outward, while the internus turned it in, would have been helpful, if not entirely corrective. A simple esotropia could not have been thus corrected; so it appears possible that in simple cases he had learned to divide only the internus. Since Taylor left nothing descriptive of the cause (termed by him "Vera Causa") of esotropia, and failed to print, either in pamphlet or lay press, anything as to the method of his operation, one can only surmise what he really thought and did. It is certain that a whole century intervened between him and Stromeyer, during which time no advance was made in the practical study of the errors of the ocular muscles.

The author almost feels that he should apologize for making any reference to Taylor, the quack, who deserved contempt while living and oblivion after death.

A more pleasant task presents itself in a brief study of the work of the immortal Donders, who gave so much thought to the etiology of heterotropia. His investigation into the relationship between accommodation and convergence proved conclusively that hyperopia is one of the factors of esotropia. This doctrine is almost universally accepted, and there seems to be absolutely no room for doubting its truthfulness. It must be granted, however, that Donders placed too much emphasis on this potent factor. If hyperopia were even the chief cause of internal squint, the cases demanding operative interference would be few and far between. Hyperopia must occupy a secondary place as a causative factor of esotropia; nevertheless, it is an important place, for a removal of this cause, by the wearing of convex lenses, early in childhood, often will make the other cause or causes inoperative. The world is indebted to Donders for this knowledge, and for acquiring and imparting it he deserves a monument.

Finally, before taking up systematically the study of heterotropia, it may be stated that it has always been a matter of observation that some cases of internal squint became cured without artificial aid. This spontaneous cure came as the patient grew older, and doubtless depended on the fact that the brain-centers controlling the ciliary muscles no longer generated so great an impulse for these muscles, such as, because of association, would have continued to over-excite the centers controlling the interni. The diminished nerve impulse coming to the interni gave the externi a chance to swing the visual axes into positions of harmony. It is not explainable how other forms of heterotropia could ever recover spontaneously, and it is doubtful if they ever have thus recovered.

As early as the seventh century of the Christian era an appliance was devised for straightening cross-eyes. It consisted of a mask with a hole in it for each eye, which the patient was compelled to wear. There may have been some cures, but the annoyance to the wearer must have been great. The practice may have been abandoned, but, if so, it was revived again by Paré in the sixteenth century.

Classes of heterotropia. There are two classes of heterotropia—the one occurring at any period of life, and always due to paralysis or paresis of one or more of the ocular muscles, and practically always curable by medication; the other occurring in infancy or early childhood, and never caused by either paralysis or paresis. The former will be studied under "paralysis and paresis of the ocular muscles," where the means of making a differential diagnosis will be set forth. It will be studied as paralytic heterotropia.

Comitant heterotropia. Of this condition there are the several varieties that have already been mentioned, each of which will be studied separately from the standpoint of both etiology and treatment. In lateral heterotropia, although the visual axes are not properly related—either crossing within the point of view, as in esotropia, or crossing beyond the point of view, often being parallel, or even divergent, as in exotropia—the two eyes, nevertheless, are made to move equally far directly to the right or left, or in any oblique direction—that is, the one visual axis accompanies the other in every movement, in any direction, the degree of variation from the normal always remaining the same. In vertical heterotropia one visual axis rises above the other as in hypertropia, or one visual axis falls below the other, as in catatropia; but when the two eyes are rotated directly up or down, or in any oblique direction, the angle of deviation always remains the same. In comitant cyclotropia, it is reasonable to suppose that the vertical axes diverge or converge the same in all movements

of the visual axes. No better word, therefore, could be chosen for defining these conditions than "comitant." The old term, "concomitant," is probably neither better nor worse than the shorter term adopted by Maddox, Jackson, and other authors.

The term "comitant" would not be needed except that it makes it easy to distinguish true heterotropia from paralytic heterotropia. In the discussion of the latter, it will be shown that, in some one part of the field of rotation, the visual axes will be properly related, giving binocular single vision, whatever muscle may be paralyzed; while rotation in the opposite part of the field will be attended by a lagging behind of the visual axis of the eye to which the affected muscle belongs, which will always be shown by diplopia, and often may be detected by the observer.

Diplopia, under ordinary conditions, does not manifest itself in comitant heterotropia, for the reason that the occurrence of the error early in life has made it possible for the mind to suppress the images in the wrongly-directed eye, that otherwise would have interfered with objects seen by the properly-directed eye. Equal deviation in all positions of the eyes and no diplopia means comitant heterotropia; unequal deviations—none at all in one direction, but greater or less in the opposite direction, with single vision in one part of the field and diplopia in the opposite part—mean paralytic heterotropia. In the former there is no disturbance of locomotion, while in the latter the patient becomes more or less dizzy. In the former, the secondary deviation is equal to the primary deviation; in the latter, the secondary deviation is always greater than the primary.

The etiology of comitant heterotropia can be studied to better advantage in the discussion of the individual varieties.

Compensating heterotropia. Before studying the individual varieties of comitant heterotropia, that heterotropia which is in the interest of binocular single vision deserves some consideration. There are several varieties of compensating heterotropia. The one which has been studied in the section devoted to **Oblique astigmatism,** properly termed compensating cyclotropia, need not be more than mentioned here.

The recti muscles may be perfectly developed, their attachments may be ideal, and their innervation centers may be faultless; nevertheless, if there is any form of anisometropia, there must be some form of heterotropia whenever the visual lines are made to sweep from the primary point to some other point of view. If the right eye is emmetropic and the left eye hyperopic, the image of a square will be larger in the former than in the latter. When the point of fixation is the

center of the square, the recti will have the visual axes in the same plane and will cause them to intersect at the point of view. If the point of view is to be changed from the center of the square upward, so as to fuse the upper border, it becomes evident that the visual axis of the right eye must rise higher than the visual axis of the left eye. Without this compensating hypertropia these borders could not be fused. Again, if the point of view is to be changed from the center of the square downward, so as to fuse the lower border, the visual axis of the emmetropic eye must travel farther than that of the hyperopic eye in order to fuse the lower borders. The cause of the fusion is a compensating catatropia of the emmetropic eye. If the point of view

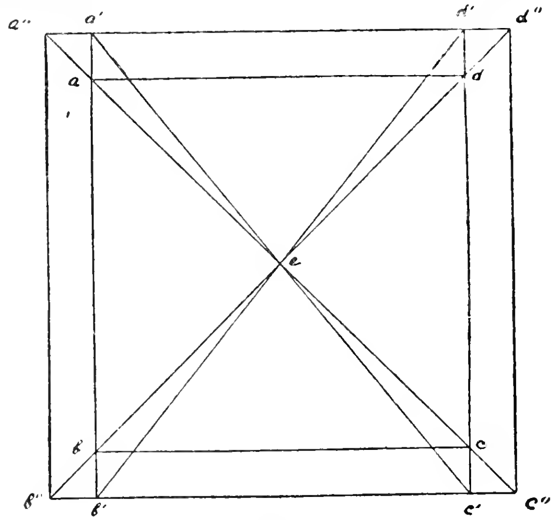


Fig. 41.

is to be changed from the center of the square to its right border, the visual axis of the right eye must sweep farther to the right than that of the left eye, or the borders cannot be fused. This is accomplished by a compensating exotropia of the right eye. Likewise there must be a compensating esotropia of the right eye, if the point of view must be changed from the center of the square to its left border. All of this is illustrated by Fig. 41, in which a–b–c–d represents the square as seen by the hyperopic eye, and a″–b″–c″–d″ represents the square as seen by the emmetropic eye. The distance from e to the line a″–d″ is greater than to the line a–d.

The same figure shows that if one eye were emmetropic and the other eye were myopic, the larger square—a″–b″–c″–d″—would be seen by the myopic eye, while the smaller square (a–b–c–d) would be seen by

the emmetropic eye. In such a pair of eyes the compensating heterotropia would be confined to the myopic eye.

Again referring to the same figure, if one eye had myopic astigmatism, the meridian of greatest curvature vertical, it would see the square as a′–b′–c′–d′, while the other eye, being emmetropic, would see the square as it really is—a–b–c–d. In such cases there would be no compensating lateral heterotropia, for a–b coincides with a′–b′ and d–c coincides with d′–c′; but there will be vertical compensating heterotropia, for the reason that e is nearer a–d and b–c than it is to a′–d′ and b′–c′.

In the same way all forms of anisometropia may be studied, showing the necessity of compensating heterotropia on the part of the eye having the greater refractive power, or the eye that is longer.

As compensating cyclotropia is always cured by the application of obliquely-placed cylinders (see **Oblique astigmatism**), so compensating lateral and vertical heterotropias are cured by the lenses needed for the correction of the focal errors. It is more necessary to correct unequal refraction, though the errors be not great, than it is to correct greater errors that are equal in the two eyes.

Prisms and lenses rendered prismatic by decentration cause compensating heterotropia in the direction of the apex of the prism; therefore, prisms, given for constant wearing to an exophoric, cause compensating exotropia; prisms given to an esophoric develop a compensating esotropia; and a prism placed base down for the relief of a hyperphoria generates a compensating hypertropia of that eye.

In spherical anisometropia the law of direction is interfered with, so far as the eye of greatest refraction is concerned, except when the two eyes are in the primary position. When there is astigmatism of one eye and emmetropia, hyperopia, or myopia of the other, there can be no heterotropia in the direction of that principal meridian of the astigmatic eye which has the same radius of curvature as the non-astigmatic cornea of the other eye; but in the direction of the other meridian there will be compensating heterotropia. In the compensating heterotropia caused by prisms and decentered lenses there is interference with the law of direction in all parts of the field of view.

Decentered corneas and misplaced maculas. There are two other causes for compensating vertical and lateral heterotropia. The one is a decentration of the cornea; the other is displacement of the macula. It would probably be more nearly correct to say that there is but one other cause—that is, decentration of the cornea. The antero-posterior axis of the eye, that axis controlled by the recti muscles, which must always be at right angles to the equator of the eye, can be none other

than the visual axis. Commencing always at the fovea centralis, it passes always through the center of retinal curvature and thence through the center of an ideally placed cornea; but if the cornea is not properly centered, the visual axis passes through some other part than the center. The posterior pole of the eye, whether near to or far away from the optic disc, or higher or lower, is the center of the macula; the anterior pole may or may not be the center of the cornea. In ideal eyes—eyes that can see best or can be made to see best—the anterior pole is the center of the cornea. The antero-posterior axis of the eye, as given by anatomists following Helmholtz, and adopted by many writers of books on the eye, has its beginning at the center of the cornea, passes backward through the center of rotation, and strikes the retina, maybe at the macula, but is just as likely to strike it elsewhere. The error is in giving the anterior pole a fixed location—the center of the cornea. Such an axis can be at right angles to the true equator of the eye in which lie the vertical and transverse axes of the eye, only when it coincides with the visual axis. It can be of value only in determining the extent of the decentration of the cornea, or how much the cornea lacks of occupying the ideal position.

In true compensating heterotropia, retinal images on the maculas are either sharp or can be made so; but when there is decentration of the corneas, the rays of light that strike the maculas are never perfectly focused, nor can they be made to focus perfectly by any artificial means. In true compensating heterotropia, that caused by anisometropia, or by prisms, there is interference with the law of direction. This is not true of decentration of the cornea; for the visual axis points directly to the source of light, although the eye appears to be pointing in some other direction as indicated by the position of the center of the cornea. The heterotropia, then, is apparent, and not real; therefore it cannot be properly called a "compensating heterotropia." The angle gamma measures the apparent deviation of the eye and the real displacement of the cornea.

When an eye whose cornea is ideally situated is examined with the Javal ophthalmometer, the reflected disc will have its center coincide with the center of the cornea; but if the cornea is displaced out, the reflection will be more from the nasal side; if displaced in, the reflection will be in greater part from the temporal side; if displaced down, the greater part of the reflection will be from the upper part of the cornea; and if displaced up, the reflected image will be more below than above. Oblique displacement of the cornea will show an oblique displacement of the reflected image of the ophthalmometer disc. These examinations, to be accurate, must be made while the patient is looking

directly into the center of the telescopic tube, and the reflected image must be looked at through the center of the leveling slit above the telescope. A considerable proportion of corneas thus examined will show slight displacements, but rarely more than 5°. When the angle gamma is much in excess of 5°, it means that the acuteness of vision cannot be made equal to 20–20.

The various forms of heterophoria, and any one of the true heterotropias, may be found in eyes whose corneas are not perfectly centered. For apparent heterotropia nothing can be done; so, therefore, nothing should be attempted. In operating for the relief of either true heterophoria or true heterotropia, it should be known whether or not there is a false heterotropia as well, else the treatment might result disastrously.

The new-formed physiologic macula that some think they have found in a squinting eye, is the old macula of an eye whose cornea is not correctly placed. There is no part of one eye, save the macula, that can harmonize with the macula of the other. Because of opacities in the refractive media, or because of disease of the choroid behind the macula, a peripheral part of the retina of that eye must be used, but it can never be made a macula; it can never be made to harmonize with the macula of the healthy fellow eye.

COMITANT ESOTROPIA.

This condition—known also as internal strabismus, internal squint, and cross-eyes—is the most common form of heterotropia. It always occurs in early life, usually at the age of two or three years. The conditions causing the error exist from birth, and only one of the several natural causes undergoes any change, at any time, after birth. In the greater number of cases it is the character of the nerve impulse to the ciliary muscles that causes over-stimulation of the third conjugate innervation center, which over-stimulation causes an actual deviation, when previously there was only a tendency toward deviation—a conversion of an esophoria into an esotropia. Why this change should not occur earlier than the second or third year is variously explained. Usually authors are agreed that children look at near objects but little until two years old, at which time they begin to take interest in toys and pictures, looking intently at them, at close range. Children who become esotropic are nearly always hyperopic, hence are forced to use their ciliary muscles in far vision, which means that, in near vision, an excessive nerve impulse must be generated and sent to these muscles. A correspondingly increased impulse is sent to the interni, which are naturally too strong for the externi, and the eyes cross.

Maddox teaches in his work, *"The Ocular Muscles,"* that the lenses increase in density even in infancy, and by the time the child is two or three years old a greater impulse is needed by the ciliary muscles to effect the necessary change in the convexity of the lenses. This increase of ciliary impulse is attended by a corresponding increase of the convergence impulse, which develops the esotropia. This would occur whether the child were hyperopic or emmetropic. An acceptance of either explanation throws the immediate blame for the crossing of the eyes on the ciliary muscles.

Whatever may be the reason for the short delay in the manifestation of esotropia, there must be a cause or causes that finally develop the condition. The following factors will be discussed in the order of their importance: Esophoria, hyperopia, hyperphoria of one eye and cataphoria of the other; a lower state of visual acuity in one eye than in the other, either from some congenital abnormality in the perceptive, transmitting, or receptive part of the apparatus, or some opacity or irregularity of the refractive media, either congenital or the result of disease, or because there is a greater error of refraction in one eye than in the other. Finally, the whole of the macula in one eye may be connected with one side of the brain, while the whole of the macula in the other eye may be connected with the other side of the brain. A sixth complication, if not a cause, is a plus or minus cyclophoria.

Esophoria as a cause. It is safe to say that without esophoria there can be no esotropia; but ordinarily esophoria must be aided by one or more of the other causes in the production of esotropia. Esophoria, when high in degree, may eventuate in esotropia, and at the usual age or earlier, when there is no hyperopia, even when the refractive error is myopic. When esophoria alone is the cause of esotropia, the actual turning occurs when the externi, always too weak as compared with the interni, give up the task of so antagonizing the interni as to make binocular vision possible. At this time the mind selects one eye for use, and the other is allowed to turn into the position predetermined by the excessive power of its internus. If its plane of action coincides with the horizontal plane of the eye, the position assumed will be directly in toward the nose; if the plane of its action is elevated, its attachment being too high, the eye will turn up as well as in and will be torted in; but if its plane of rotation is depressed, its attachment being too low, the eye will be turned down as well as in, and will be torted out. At the time of the beginning of the in-turning, the mind, in the interest of single vision, begins the work of suppressing the images on the retina of the in-turned eye. If the esotropia is not periodic or alternating, the work of mental suppression is soon accom-

plished, the patient becoming mind-blind in the crossed eye. When an esophoria alone is the cause of esotropia, the error probably shows itself earlier than usual. Spontaneous recovery, in such a case, will never occur.

Hyperopia as a cause. When hyperopia, or hyperopic astigmatism, is one of the causes of esotropia, it is not the quantity of the error, but the character of the required impulse for its correction, that enters as a factor. A greatly excessive impulse may be needed for the correction of a small error, while an impulse not so great gets a more ready response on the part of the ciliary muscles for the correction of a greater error. The excessive activity of the center for the ciliary muscles (the tenth) causes over-excitation of the third conjugate center, thus developing a pseudo-esophoria. This grafted on an intrinsic esophoria may readily convert it into an esotropia. The foundation for every permanent esotropia is intrinsic esophoria. An esotropia caused by hyperopia alone will be periodic, and never permanent. In such cases, suppression of images is impossible. In cases of esotropia, in which spontaneous recovery takes place, hyperopia has been the chief cause. If the esotropia spontaneously cured has lasted very long, mental suppression has already accomplished its work, and the eye once crossed remains low in visual acuity.

The position assumed by an esotropic eye when the two factors, esophoria and hyperopia, have acted together, is always determined by the character of attachment the internal rectus may have. The eye may be turned straight in, or in and up with inward torsioning, or in and down with outward torsioning.

The esophoria unassociated with hyperopia, in many cases, would not have caused esotropia; hence it appears reasonable to conclude that a correction of the hyperopia would result in a reconversion of the esotropia back into esophoria. This is just what is accomplished in a large per cent. of the cases of esotropia that are brought early to the oculist. Thus cross-eyes are straightened without operation; but this does not mean that an operation may not be required for the cure of the esophoria, for the relief of reflex troubles.

Hyperphoria and cataphoria as causes. The plane of action of the superior and inferior recti is such that they not only turn the eyes, respectively, up and down, but they also turn them in. Imbalance of the superior and inferior recti, whether that imbalance is shown in a hyperphoria of one eye and a cataphoria of the other, or in a double hyperphoria or in a double cataphoria, will become a factor in the production of esotropia only when there is an esophoria. When these two causes act together, the crossing will occur at the usual age (in the

second or third year); but the esotropia will be complicated by a hypertropia or catatropia. If there is an eso-hypertropia and the superior rectus is the cause of the hypertropia, there will be a minus cleyotropia of that eye. If the fellow eye becomes eso-catatropic under cover and the catatropia is caused by the inferior rectus, there will be a plus cyclotropia of this eye. In double eso-hypertropia, the hypertropia being caused by the superior recti, there will be also a minus cyclotropia of each eye; and in double eso-catatropia, the catatropia being caused by the inferior recti, there will be also a plus cyclotropia. When, in eso-hypertropia, the hypertropia is effected by both the superior rectus and the inferior oblique, there will be no cyclotropia; when, in eso-cataphoria, the catatropia is caused by both the inferior rectus and the superior oblique, there will be no cyclotropia.

There are cases of double eso-hypertropia, in which there is marked plus cyclotropia, easily observed without instrumental aid. The cause of the hypertropia in these cases is to be found in the inferior obliques, which muscles also cause the plus cyclotropia. In these cases the esotropia is wholly due to the interni. That the turning up is not helped by the interni is shown by the existence of the plus cyclotropia; for, while a too high internus will turn the eye up, it will not tort it out. Thus it appears that a hyperphoria, caused by the inferior obliques, cannot be a direct factor in the causation of esotropia. If not a cause, it must be considered as a most important complication. The possible factors of esotropia and its complications can be found only by means of a most painstaking examination with the phorometer, cyclophorometer, and tropometer, or perimeter.

Low state of visual acuity as a cause. This condition, whatever may be its cause, can be only a secondary factor in the production of esotropia; for in these cases, as in all others, esophoria is the chief factor. If the low visual acuity is due to some congenital condition, or is caused by disease or injury in early infancy, the esophoria will be transformed into esotropia in early life. If both eyes have been good for any number of years, when disease or injury renders the vision of one eye bad, or even destroys vision altogether, this eye will become esotropic, if esophoria has previously existed; if there is no esophoria, there can be no esotropia, however low may become the vision of one eye. An eye that becomes blind will continue to move in harmony with its fellow, if previously there has been no form of heterophoria. If there is known to be a certain kind of imbalance of the muscles when the vision in both eyes is good, should the vision of one eye be much reduced, or even lost, a positive prediction can be made as to the kind of heterotropia that will result: the turning will always be in the

direction of the tendency. If there is perfect balance of all the ocular muscles, diminution, or loss, of vision of one eye will not interfere with the harmonious movements of the two eyes; a blind eye, under perfect muscle adjustment, will always appear to fix the object seen with the good eye.

Faulty connection of the maculas with the brain as a cause. There are cases of esotropia in which it is impossible to fuse the two images of an object. Such cases were observed by Graefe, who defined the condition as "antipathy to binocular single vision." The cause of this antipathy, in all probability, is that the macula of one eye is connected with one side of the brain, while the macula of the fellow eye is connected with the other side of the brain. To fuse images on the two maculas their impressions must be carried to the same side of the brain, which cannot be accomplished unless the nerve fibers passing from the two maculas find their way into the same optic tract and thence go to the same cuneus. If the maculas fail to have a common connection with the brain, other retinal points that ought to correspond cannot do so, and there must be diplopia in all parts of the field. The condition, if it exists, is congenital, and the only reason why there is not annoying diplopia must be due to the habit of mental suppression acquired in infancy. Esotropia due to such a cause must occur earlier in life than is usual, possibly within the first few weeks after birth, or from the day of birth.

Pathology points to the possibility of such a cause for esotropia. A disease involving the center of sight in one cuneus, or a disease involving all the nerve fibers as they pass from one cuneus in their course to the optic chiasm, whether in the tract or farther back, must cause hemianopsia, involving corresponding halves of the two retinas, the temporal half of one retina and the nasal half of the other. Many such cases have been observed. In some cases the line dividing the blind part from the seeing part of each retina has been vertical, passing down through the macula; in other cases, while these lines were vertical, they missed the maculas, passing a few degrees either to the right or to the left of both, the two maculas falling either in the blind or in the seeing parts, in either case showing that both were connected with the same side of the brain; in other cases the dividing lines have not been vertical, the obliquity being sometimes as much as ten degrees, but the same in the two eyes. The oblique lines have passed, in the reported cases, either through the maculas or have fallen on corresponding sides. No case, so far as the author knows, has ever been reported showing that the blindness in the temporal half of one retina included the macula, while the blindness in the nasal half of the other

retina did not include the macula, else no further argument would be necessary. That pathology has shown no cases of faulty connection of the maculas with the brain is probably due to the rarity of the condition—certainly as rare as is ''antipathy to binocular single vision,'' for the one must be a synonym of the other. If the lines dividing the retinas into two halves pass, in some cases, down through the maculas, while in other cases both these lines pass either to the right or to the left of the maculas, it must be conceded as a possibility that the dividing line in one retina may pass to the right of the macula, while the dividing line in the other retina may pass to the left of the macula. In this case disease of one cuneus or of one tract would destroy the perceptive power of one macula, while the other macula would be uninvolved. There being no disease in such a case, the impress of an image on one macula would be conveyed to one side of the brain, while the impress of the image on the other macula would be sent to the other side of the brain, and there could be no fusion of the two. So far as the author can see, nothing else can account for ''antipathy to binocular single vision.''

Every surgeon of much experience with esotropia has had cases that he could not cure, however skilled as an operator. Each attempt to correct the error in such a case makes the patient worse, for the reason that, under the old condition, the power of suppression of images in one eye had been acquired, while under the new condition, the images fall on new parts of the retina of the eye operated upon, and diplopia is at once made manifest. The more nearly the readjustment of the muscles brings the eyes straight—to exactly straighten them is impossible—the more annoying becomes the diplopia. If the patient is mature at the time the operation is done, his diplopia will always be annoying, for he can never reacquire the power of mental suppression. To have let such a patient alone would have been a mercy.

Fortunately, esotropia due to the cause under discussion is rare. That the mistake of operating on such cases may not be made, the operator should give most careful study to every case. When there is great amplyopia of the esotropic eye, one may feel fairly sure that the case is not of this character; for usually a case of this kind has fairly good vision in either eye when the other is excluded, whether the esotropia is alternating, or not. But all cases of alternating esotropia, with fairly good vision in each eye, do not belong to this hopeless class. In any case of esotropia the fusion test should be applied; but in alternating esotropia this test becomes absolutely essential. When the images can be fused, the case can be cured; if the images cannot be fused, a cure is impossible, and should never be attempted. The method

of making the fusion test will be given farther on, and the peculiar play of images that cannot be fused will be shown.

The varieties of comitant esotropia have already been mentioned incidentally. They may be grouped here as follows: Periodic, alternating, and permanent. The same case, at different times, may present these different conditions. Periodic esotropia is always curable; while alternating esotropia may be curable, it is always open to the suspicion that there is "antipathy to binocular single vision." Permanent esotropia is usually attended by pronounced amplyopia in the deviating eye, and practically always depends on causes that can be relieved. Occasionally a case of permanent esotropia may belong to the incurable class, in which there is "antipathy to binocular single vision."

Diagnosis. Comitant esotropia must be differentiated from apparent esotropia and from paretic esotropia. The cover test at once settles the question as to apparent esotropia, for, on covering and uncovering the eyes alternately, there will be no resetting of either eye, both visual axes always pointing toward the test object. The cover test, in comitant esotropia, always shows a resetting of both eyes when covered and uncovered alternately. Under this test there are always present the primary and the secondary deviations—the one equal to the other. In paretic esotropia the secondary deviation is always greater than the primary deviation, for the reason that if the paretic muscle is the right externus, the fourth conjugate innervation center sends an excessive impulse to the right externus, because it is paretic, and to the left internus, causing the latter to manifest excessive power. On covering the paretic eye and uncovering the good eye, the fifth conjugate innervation center sends only an ordinary impulse to the left externus and the right internus, hence the slighter deviation of the eye to which belongs the paretic muscle.

The complications of esotropia are: hypertropia of one eye and catatropia of the other, double hypertropia, double catatropia, and cyclotropia. Hyperopia and hyperopic astigmatism may also be considered as complications. In the treatment of esotropia, it is also essential that all these complications shall be either found or excluded.

The fusion test. There is no test, in the investigation of a case of comitant esotropia, so important as the fusion test. The ability to fuse images should be determined, regardless of the time it may take. If a patient could be made conscious of double vision at once, the ability to fuse could be quickly found.

The test object should be a candle or a gas jet. Placing a red glass before the good eye, the natural light is often easily found by the deviating eye, and on the corresponding side. If the red glass before

the good eye does not bring out the consciousness of the double candle, then a green or a blue glass may be held before the deviating eye, thus discoloring both images. As soon as the two discolored lights are seen, the glass before the deviating eye may be removed, when, with comparative ease, the natural light is seen by this eye, while the red light is seen by the fellow eye. If the two are not level, they should be made so by means of the proper prism, placed vertically. Now, by means of the rotary prism before the deviating eye, the yellow blaze should be made to approach the red one. If they are more than ten degrees apart, a supernumerary prism should be placed, with its base out, behind the rotary prism, when, starting again at zero, the index is again carried into the nasal quadrant; and as it revolves, the lights are brought nearer and nearer, until finally they merge into one. In the whole test the fixing eye is the good one, and the fixed object is the red light. The fusion is effected the moment the yellow image is thrown, by prismatic action, on the macula. Once fused, there should be no diplopia so long as the fusing prisms remain unchanged. Whenever fusion is found possible, the case is curable.

If there is antipathy to binocular single vision, the false (yellow) light can be made to approach the true (red) light, but cannot be made to fuse with it. The two will ''kiss'' and then recede, or the one will rise above or fall below the other and pass to the opposite side. Any number of repetitions of the effort to fuse, by means of the most careful use of the rotary prism, will result in failure. Such a case is incurable by any and every means; and, therefore, no attempt to cure should be made. Unguarded operations certainly make these cases worse. Cosmetic results alone are attainable, and this often at the cost of annoying diplopia.

Comitant esotropia is a monocular trouble only in appearance. In reality it is binocular—a fact that should always be remembered when operations are about to be done for its relief. The binocular character of esotropia is shown by the cover test; for the moment the deviating eye is made to fix, because the good eye is covered, the latter turns in. After operations have been done on the deviating eye, it sometimes becomes easier to use this eye, at which time the fellow eye turns in, but not so much as the original eye had turned. This use of the eye that before deviated, favors the cure of the amblyopia, without detriment to the other eye.

Measurements of esotropia. There are several methods, some more accurate than others, but all of them of some value. The phorometer test is the only one that is perfectly correct; and, unfortunately, it is the hardest one to accomplish, for the reason that it is so difficult to

develop consciousness of diplopia. If diplopia could always be made manifest, the other methods of measurement would soon be discarded. The angle gamma does not interfere with the phorometer test, but it does militate against all other tests. This angle is formed at the crossing of the visual axis and the line commonly called the "optic axis," but really only a secondary visual line, at the center of the retinal curve, which is the center of rotation of the eye. For a better understanding of the angle gamma the lines whose intersection forms it should be studied. The visual axis begins always at the fovea centralis, and must always pass through the center of motion, which is the center of retinal curvature, and thence it must pass through the cornea, but at no definite point; it may be its center, but more often the point through which the visual axis passes is away from the corneal center. The visual axis is the antero-posterior axis of rotation. It is strange how the line of fixation should ever have been conceived as other than the visual axis. The so-called "optic axis" is the line that must begin at the center of the cornea and must pass through the center of rotation and may reach the macula, but more often misses it. This line, unless it coincides with the line of fixation, cannot be an axis of rotation, for the reason that it cannot pass through the equatorial plane at right angles; for the equatorial plane must be at right angles to the line of fixation—the visual axis. The point always common to these two axes, or lines, is the center of rotation of the eye, and the angle formed by their intersection is the angle gamma. The average size of this angle is about five degrees, though in an ideal eye it is nothing. When this angle is to the nasal side of the visual axis, the eye that is straight would appear to be esotropic; if to the temporal side, the eye would appear to be exotropic. The angle is more often temporal than nasal; hence an esotropia would appear less than it really is, while an exotropia would be exaggerated by it. This angle can always be measured by the perimeter, and, when known, can be taken from or added to, as the case may be, the esotropia that has been previously measured in any other way than by the phorometer.

Measurement by the phorometer. A red glass should be placed before the good eye. Before the deviating eye should be placed the rotary prism in the position for testing for lateral heterophoria, with the displacing prism of six degrees, base up, in the cell toward the eye. The red and the yellow blazes of the candle or gas jet having been found, the latter will appear more or less removed from the vertical line passing down through the red light and in the direction corresponding to the deviating eye. The fifteen-degree supernumerary prism should be placed, base out, in the front cell, which will carry

the yellow light just that far toward the vertical line passing through the red light. Revolving the rotary prism in the nasal arc, the yellow light is carried still nearer the vertical line, which it may be made to reach at some point between zero and ten degrees; but if this falls short, the rotary prism should be revolved back to zero, and a stronger supernumerary prism (twenty degrees, twenty-five degrees, or thirty degrees) should be placed in the anterior cell. Now the rotary prism should be turned again in the nasal arc and then stopped at that point where the patient declares the yellow light directly under the red one. If the twenty-five-degree prism is in the front cell and the rotary prism stands at seven degrees, the prism-degree measurement of the esotropia is thirty-two degrees, one-half of which would give the degrees of arc—viz., sixteen degrees. As already stated, the angle gamma does not have to be considered in connection with the phorometer measurement. It would be very difficult to take the measurement of esotropia with the prisms of the refraction case held by the hands of the operator. Though this would be tiresome and tedious, it, nevertheless, would be accurate. This measurement is in degrees of prism.

Measurement by the perimeter. Have the head placed as if the purpose were to take the field of the non-deviating eye, which should be made to fix the point in the center of the semicircle. A candle or small electric light should be moved along that arc toward which the deviating eye points, and it should be stopped the moment that the image, reflected from the center of the cornea, the light, and the eye of the observer are in line. The number on the perimeter arm, at the point where the light was stopped, gives the measurement of the deviation in arc degrees. If the esotropia thus measured should appear to be twenty-five degrees, it will be more if the angle gamma is temporal, or less if this angle is nasal. The next step is to determine the presence or absence of the angle gamma, and, if present, its size. To do this the good eye must be covered while the patient fixes, with the esotropic eye, the point in the center of the perimeter arc. When the candle is held immediately behind this point, if the image is reflected from the center of the cornea so that the image, the light, and the eye of the observer are in line, there is no angle gamma, and, therefore, nothing is to be taken from nor added to the measurement of the esotropia; but if the light must be moved in the temporal arc for the image, the light, and the eye of the observer to be in line, there is an angle gamma, the size of which is shown by the number at the point on the perimeter arm at which the light was stopped when the image appeared reflected from the center of the corneal surface. The angle thus formed being temporal, it should be added to the measurement of the apparent eso-

tropia, in order to show the quantity of the real deviation; but if, in finding the angle gamma, the light has been moved into the nasal arc, the angle would be nasal, and should be subtracted from the measurement of the apparent esotropia, in order to show the quantity of the actual deviation. If the perimeter is carefully used in the manner set forth, the results must be correct. It is applicable to all cases of esotropia in which the deviating eye can be made to fix when the good eye is covered; while the phorometer method can be used only in those cases in which, by means of a red glass before the good eye, consciousness of diplopia can be awakened.

When the squinting eye cannot see, therefore cannot fix, the angle gamma cannot be measured, and for this reason it cannot be taken from nor added to the perimeter measurement of the esotropia.

The tape measurement. Priestly Smith's method of measuring esotropia is easy and fairly accurate. By this method the angle gamma is not considered. To make this test one must have an ophthalmoscope; two tape lines, each one meter long; and a candle, a lamp, or a gas jet. The tape lines, at one end, should be fastened to a ring large enough to allow the handle of the ophthalmoscope to pass through it, while the other two ends should be free, and on one tape should be a scale indicating arc degrees. With the light above and behind the patient, the operator seats himself one meter in front of him. He gives to the patient the free end of the unmarked meter tape, and tells him to place it immediately beneath his good eye; and then, with the ophthalmoscope in front of his own eye which corresponds with the patient's non-deviating eye—that is, his right eye, if it is the patient's left eye that turns in—he withdraws from the patient as far as the tape will allow whose ring end is fastened to the ophthalmoscope, or to the thumb of the hand holding the ophthalmoscope. He directs the patient to fix the hole in the mirror while he reflects the light into the fixing eye. If there is no angle gamma, the operator sees the image of the blaze reflected from the center of this cornea; but on reflecting the light into the deviating eye, while the good eye still fixes the hole in the mirror, the image of the blaze will be seen toward the temporal margin of this cornea, the distance from the center corresponding to the amount of the esotropia. The operator now takes the marked meter tape in his free hand (he holds the mirror before his right eye with his left hand, and vice versa) close to the attachment to the ring, and, slowly extending it at right angles to the other tape, he directs the patient to look at his moving thumb with his good eye. Throughout this step in the test, the light from the mirror is kept on the cornea of the deviating eye, and the operator watches the reflected image as it

approaches the center of the cornea. The moment the image is seen at the center of the cornea the operator stops the movement of his hand, and immediately reads on the scale the number of degrees the good eye had to move toward the nose in order that the deviating eye might become straight. Since the two eyes move comitantly, the reading on the scale is the measurement of the esotropia. This method is not as accurate as either the phorometer or the perimeter methods, for the reason that one cannot be certain that the marked tape is at right angles to the unmarked tape.

Linear measurement. Lawrence's strabismometer, which is the best means for taking the linear measurement of squint, is rapid, but not accurate, in its work. The lid piece is concave on one side so as to rest evenly against the lower lid; on the convex side it is graduated in millimeters in both directions from the central point, which is marked zero. In making the test, the operator covers the good eye, thus forcing the patient to fix some distant object, immediately in front, with the deviating eye. The instrument is now placed in contact with the lower lid of the now-fixing eye, so that the point marked zero may be directly in line with the center of the pupil. On uncovering the good eye, it at once fixes the test object, while the deviating eye turns toward the nose. The extent of the turning in millimeters is shown by that mark on the scale that falls immediately beneath the center of the pupil.

Hirschberg's method. By this method accuracy cannot be attained. The test object is a candle held twelve inches from the patient, and immediately before him on a level with his eyes. With both eyes uncovered he is directed to look at the candle. The image of the candle is reflected from the corneal center of the fixing eye, but from the temporal side of the cornea of the esotropic eye. Hirschberg estimates that the deviation is ten degrees or less, if the reflected image is nearer the center than the margin of the pupillary area; from twelve degrees to fifteen degrees, if the image is at the margin of the pupil; twenty-five degrees, if the image is halfway between the center of the cornea and its margin; from forty-five degrees to fifty degrees, if the image is at the corneal margin. Esotropic cases were divided by Hirschberg into these several groups that he might determine the kind of operations to be done in any individual case. Since complete tenotomies ought never to be performed on esotropes, the Hirschberg method of testing is of no practical use.

Symptoms of comitant esotropia. There is no nervous tension of the externus of the esotropic eye, for the position assumed by this eye is that of equilibrium of all the recti and the oblique muscles. The tension of the externus of the fixing eye may be lessened, if not relieved,

by a turning of the face toward the corresponding side, so as to let the visual axis cross the extended median plane of the head between the eye and the object of fixation. Headache or other symptoms, in these cases, usually attributed to eye-strain, depend largely on the abnormal tension of the externus of the fixing eye, though this is sometimes relieved by an acquired side-pose of the head. But in some of these cases it may depend on the nervous tension of the ciliary muscle in its effort to correct the hyperopia or hyperopic astigmatism of the fixing eye, together with the associated tension of the ciliary muscle of the non-fixing eye; or it may result from the effort of the obliques to parallel the vertical axis of the fixing eye with the median plane of the head.

Amblyopia. The one subjective symptom common to most cases of permanent esotropia, and that may exist unnoticed for many years, is amblyopia of the non-fixing eye. While in some cases this may be congenital, in most cases it is acquired. The blindness is in the mind, and not in the eye. Nature has provided only two methods by either one of which a person may be freed from the annoyance of seeing everything double: First, the proper regulation of the visual axes by the recti muscles, so that they may always be in the same plane and converged at the point of view, and the paralleling of the vertical axes of the eyes with the median plane of the head, thus making binocular single vision possible; second, in the absence of any one or all three of the conditions essential to binocular single vision, then mental suppression of the images in one eye. The habit of mental suppression cannot be established except in infancy and early childhood. Once this habit is established, it is hard to break at any period of life; but the task can be more easily accomplished early in life than in later years. In all cases it is probable that the amblyopic eye would become useful, if accident or disease should destroy the fellow eye. W. B. Johnson, of Paterson, N. J., has observed and reported two such cases. His report has done much to prove that amblyopia ex anopsia is not a myth. Faithful exercise of the little visual power of the amblyopic eye, by covering the good eye, will greatly improve its vision, especially in young persons. Without this special exercise it has often been noticed that vision improved in the formerly non-fixing eye after the muscles had been readjusted so as to properly regulate the visual axes and the vertical axes. There is now but little room for doubting that the amblyopia of esotropia is mental, and not ocular.

The chief objective symptom is disfigurement. However beautiful a young lady may be otherwise, if her eyes are crossed that beauty is marred; and if she is otherwise unprepossessing, crossed eyes could but

render her more so. A young man afflicted with esotropia cannot be so handsome as he would be if his eyes were straight. A girl or boy, a woman or man, with esotropia is at a decided disadvantage from a cosmetic point of view; and if there were no other reason for operating, this one would be sufficient.

An objective symptom that should never be neglected in the study of any case of esotropia is the turning in of the good eye when under the cover, at which time the fellow eye must become the fixing eye. The secondary esotropia should be equal to the primary; but if the secondary esotropia is greater than the primary, it points to paretic, and not to comitant, esotropia.

Complications of esotropia. These are errors of refraction; hypertropia, single or double; catatropia, single or double; hypertropia of one eye and catatropia of the other; and cyclotropia, either plus or minus. Hypertropia, catatropia, and cyclotropia will be studied further on in this section. Here it may be said that these errors, if unassociated with esotropia, would often be phorias, and not tropias. Nevertheless, before operating for esotropia, it is important to know if these errors exist; it is also important, before operating for esotropia, to study well the refraction of the two eyes, and to correct those errors (hyperopia and hyperopic astigmatism) that are not only complications of esotropia, but act as causes also.

Treatment of esotropia. Hyperopia and hyperopic astigmatism, often a complication of esotropia, are just as often causative of this condition. A very few cases of esotropia have, for their chief causes, these errors of refraction. It is only a case of this kind that eventually recovers spontaneously; but spontaneous recoveries are rare. Nor should these cases be allowed to wait for such a recovery, which would be years in coming; but they should be cured at the earliest possible moment. The only treatment needed for such cases is the full correction of the hyperopic error, and at the earliest time possible. Such a patient, if only two years old, will wear the correcting lenses kindly, because of the relief experienced. If the spectacles are not given to the little fellow promptly after his morning toilet, he will call for them. It is often interesting to experiment with such a case by having him look at some distant object one moment through the lenses, when the eyes will be straight, and then a moment without the lenses, when the eyes will cross. The repeated raising and lowering of the lenses will show alternate crossing and straightness. One who has seen these changes cannot reasonably doubt the effectiveness of convex lenses in the treatment of esotropia.

There are two reasons for the early adjustment of convex lenses in

the treatment of esotropia. One is that it is in the earliest years of life that the power of mental suppression of images in the deviating eye is acquired. To prevent this amblyopia is to cure the esotropia; or, if the habit of suppression has already been formed, the early correction of the esotropia gives the patient a chance to recover the lost vision with greater ease than would be possible in later years. The other reason for the early correction of the hyperopic error that has caused the esotropia is the relief the lenses give to the brain-center that supplies power to the ciliary muscles. With the convex lenses on, this brain-center is no longer over-stimulated, and consequently the third conjugate center is no longer over-excited. The extra nerve force that must be expended by these centers, if the hyperopic error remains uncorrected, must be at the expense of nerve force needed by other centers.

Every little child whose eyes are crossed should be given the chance of a cure by means of spectacles. If the hyperopic error is the whole cause of the esotropia, the lenses will certainly effect a speedy cure; if the hyperopia is only one factor, while esophoria is the other factor, in the production of esotropia, the early correction of the focal error will often make it impossible for the esophoria to continue to transform itself into esotropia. The eyes can be straightened, in some of these cases, by means of convex lenses, but the esophoria will remain. Later, because of nervous symptoms, the esophoria may demand treatment, either surgical or non-surgical. To do any kind of surgery for the cure of an esotropia that has for its sole cause a hyperopic error must result in harm. In early life no case of esotropia that is hyperopic should be subjected to operation until it becomes evident that convex lenses cannot straighten the eyes. It is doubtful if the almost universal practice of keeping such eyes under the influence of atropine is helpful, but certainly both eyes should be under the influence of either atropine or homatropine at the time the measurements are taken, and the full error thus found should be corrected. Worth is correct in his advocacy of atropine in the good eye only, after the convex lenses have been given, and the reason for this is not far away; it allows the child to use the better eye for distance, but forces him to use the deviating eye for near objects—a very good way for curing the amblyopia. For the same reason atropine could be used in the good eye when there is any other form of heterotropia.

If, in a month or two, convex lenses do not cause the eyes to swing straight, surgery should be resorted to, however young may be the patient. By ''surgery'' is meant the right kind of surgery—partial tenotomies of the interni, with or without shortenings of the externi.

A complete tenotomy in the case of a child should never be done, and advancements should be avoided. Very slight operations, if done in early life, will accomplish as much as more extensive operations done in later years; but an esotrope never grows sufficiently old to justify complete tenotomies.

If the refraction of the eyes is myopic, this error cannot have been a factor in the production of the esotropia; hence the correcting lenses cannot aid in the cure. Surgery alone can bring these eyes straight. Such a case of esotropia can never recover spontaneously. An esotrope who is emmetropic can be cured only by surgery. Atropine used in the good eye will help after surgery has been resorted to.

Esotropic patients who have been allowed to go for years without treatment, whatever may have been the cause or causes, become more or less amblyopic in the deviating eye. In many of these cases the correction of the hyperopia, if it had been given early, would have speedily straightened the eyes; but if this correction is withheld until the suppression habit has become established, the cure, if it can ever be effected by the convex lenses, is much more tedious. Nevertheless, a fair trial of the lenses should be given, a great aid to which will be the forced use of the deviating—amblyopic—eye, for a short while, several times a day. This is done by placing a flap before the good eye, thus compelling the mind to receive the impression of the images on the retina of the bad eye. At such time, and at all times, the correcting lenses should be worn. At first only large objects in the distance should be observed; later, pictures or large print should be looked at. If the patient is old enough, he will observe the improved state of his vision from week to week, and will thus be encouraged to continue; if the patient is a child, the exercise should be enforced, for the little one cannot appreciate the results. This practice at first may be continued only for a few minutes—from ten to thirty; later, it should be prolonged for an hour or more; and, in either case, it should be repeated two or more times daily. The training of the mind to use the amblyopic eye is the best means for the beginning of the development of the fusion power. Whether a child or a grown person, the use of atropine in the good eye will help to train the mind to use the bad eye.

This training of the mind to use the amblyopic eye is necessary even in those cases that must be subjected to operations, else binocular single vision may not be obtained. The chief object in view in the treatment of esotropia, whether by lenses or by operations, or by both, is the establishment of binocular single vision. There should be fewer fail-

ures in this direction in the future than in the past. The forced use of the amblyopic eye will make success more certain.

After a few months of training, as set forth above, the stereoscope can be brought into use. At first the two pictures used should be unlike, but of such a nature as to be easily combined. The best example is the picture of a bird before one eye and the picture of a cage before the other. The bird, at first outside of the cage, will be observed by the child to approach and enter it, finally resting on the perch. Other pictures that can be associated should be provided. Later, cards may be used, on one end of which is drawn one part of an object; on the other end, the remaining part of the object. If the complete object is seen, the retinal images have been fused. Later, the pictures ordinarily used in the stereoscope may be given. To be certain that these pictures

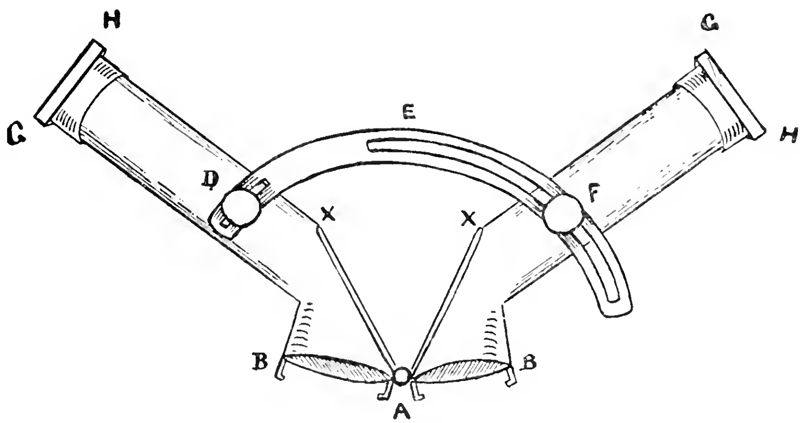


Fig. 42.

have been fused, it becomes necessary to make some change in each at different parts; for example, cut off the upper left hand corner of one picture and the lower right-hand corner of the other. If an unmutilated picture is seen, the two retinal images have been fused. Many other changes, such as placing different kinds of marks on the pictures, would readily suggest themselves. When the esotropia is of high degree training by means of the ordinary stereoscope is impossible.

The best means for training the fusion power is, probably, the Worth reflecting stereoscope, or amblyoscope, shown in Fig. 42. This instrument can be used in any and all cases of esotropia; but before undertaking the training of the fusion faculty by this means, the amblyopia of the deviating eye should be treated in the manner already set forth. As shown in the cut, the Worth instrument consists of two symmetrical

halves; each half is made by uniting two tubes, a long and a short one, at an angle of one hundred and twenty degrees, and the two halves are joined by the hinge shown at A. These halves are further connected by the brass arc D–E–F, in which are two slots, and by means of which the distal ends of the tubes may be made to vary the distance between them. At D and F are binding screws for "fixing" the proper relationship of the tubes, when it has been attained, for any given pair of esotropic eyes. By placing the binding screws at the inner ends of their respective slots the instrument is in adjustment for sixty degrees of esotropia; and by moving these screws to the outer ends of their respective slots the instrument will be in adjustment for thirty degrees of exotropia.

At G–H of each tube there is an arrangement for the insertion of translucent picture slides. At A–X of each tube there is an oval mirror. At the ocular ends A–B there are lenses of a certain power, which may be supplemented by other lenses that may be needed by any individual case, for making sharp the outline of the images reflected from the mirrors.

In using this instrument for training the fusion faculty, images that differ, and yet can be associated, should be placed in the distal ends of the tubes. The best example is the picture of a cage for one tube, and that of a bird for the other. The tubes must be related corresponding to the degree of deviation of the esotropic eye, so that the reflected image of the one picture may fall on one macula, while that of the other falls on the other macula. At first the patient may see only the cage, and not the bird, or vice versa. By increasing, relatively, the intensity of the light entering the tube that is before the squinting eye, the bird is finally seen in the cage. Any two pictures that can be associated may be used, but none can be better than those of the bird and the cage. Later, one may place in the tubes pictures that represent different parts of an object, the fusion of the two making the thing represented in parts appear as a whole. A very great variety of such pictures should be on hand, so as to make the exercise interesting to the little patient.

These exercises should not be undertaken until treatment by other means already mentioned has relieved, to a considerable extent, the amblyopia of the deviating eye. It would be well if the fusion faculty could be trained before operating, if circumstances will allow, and certainly before the final operations are done, if the best results are to be expected.

Bar-reading. Perhaps one of the best means for perfecting the fusion faculty is bar-reading. A strip of card-board, half an inch

wide—or even a pencil, though this is hardly wide enough—should be held between the eyes and the printed page, about four inches from the latter. This will obscure some of the words for each eye, and will thus interfere with the reading, unless both eyes are being used. The words obscured for one eye are seen by the other, in binocular vision; therefore the bar does not hinder the reading; and since this is so, the bar-reading exercise may be continued for hours at a time. There can be no question as to its value.

Treatment of the amblyopia is: by excluding the good eye; by the adjustment of lenses that correct hyperopic errors; by the use of atropine in the good eye, forcing the near use of the other; by the training of the fusion faculty with the simple stereoscope or the reflecting stereoscope, and, later, by bar-reading—these are non-operative means that should be applied to all cases of esotropia, even to those that must be subjected to operations.

Operative treatment of esotropia. If all cases of esotropia could be treated at the earliest possible time—that is, when the condition first shows itself—probably not more than twenty-five per cent. of them could be cured by non-operative means. Of this twenty-five per cent. a fair proportion would require, later in life, operations for the relief of the esophoria, which had been one of the causes, probably the chief cause, of the esotropia. A cure of esotropia, in the strictest sense, would mean that every causative factor has been removed. Convex lenses, given for the correction of hyperopic errors, remove only one factor; but in doing this much, they sometimes render inoperative the esophoric factor. However, the latter can be removed only by exercise or by operations.

It cannot be emphasized too strongly that complete tenotomies are not indicated in esotropia, even though the error should be high in degree; and if complete tenotomies should not be done, it goes without the saying that the "check ligaments," so-called, should never be severed. It must be granted that some cases on whom complete tenotomies have been done have resulted in a cure of the esotropia, but it must be conceded also that a greater number have not been cured. One does not have to theorize as to the possibility of an esotropia's being converted into an exotropia by complete tenotomies of the interni, for this unfortunate result has been observed in a multitude of cases. In every complete tenotomy the control that comes from anchorage is lost. Uncut fibers of the tendon constitute the best anchorage; but if by accident all the fibers of a tendon should be cut, the divided tendon should be anchored to the globe by means of a

stitch. Otherwise the danger is great that the muscle may retract too far, and thus become a crippled muscle.

The only complete tenotomy that can be said to be at all safe is that advised by Panas. In this operation the hook is passed beneath the tendon (of the internus in esotropia), and by it the eye is rotated outward until the cornea is almost hidden behind the external canthus. This done, the force is relaxed and the tendon is completely divided. The element of safety lies in the fact that the over-stretched muscle has been rendered paretic, and, therefore, does not retract so far as it otherwise would do. The cut tendon becomes adherent to the globe before the muscle recovers from its paresis; hence its new attachment is as favorable for normal action of the muscle as it is possible for it to be after a complete tenotomy. The element of safety in the Panas operation is not sufficient to justify its adoption, in the face of the fact that there are safer operative means for the treatment of esotropia.

If shortenings or advancements are done in connection with complete tenotomies, the latter become even more hazardous.

Landolt's method of treating esotropia by advancements of the externi alone is much to be preferred to complete tenotomies of the interni; for it is not attended by the danger of converting an esotropia into an exotropia, and it offers a better chance for the giving of binocular single vision in all parts of the field.

As in all other matters, so in operating for esotropia, extremes should be avoided. "The golden mean" is not an inapt expression. One extreme, in the treatment of esotropia, is complete tenotomies of the interni and the cutting of the check ligaments, without shortenings or advancements of the externi; the other extreme is extensive advancement of the externi, without interfering in any way with the interni.

By the one method the strong muscles are made weak by setting them back (and, as already shown, the danger lies in the probability that they will be set back too far); by the other method the weak muscles are made strong by bringing their attachments farther forward, with but little danger of bringing them too far. If enough could be accomplished by the advancements, in all cases, it would be almost the ideal operation.

The ideal operation for the cure of esotropia and its complications consists of advancements of both externi, or, if in young children, shortenings of both externi, to make them stronger, and partial tenotomies of both interni to make them weaker. The object in view is to bring the strength of the externi up to the normal both as to abduction and abversion, and to reduce the strength of the interni only

to the normal both as to adduction and adversion. There is practically no danger of over-reaching the limit in either of the two directions.

There are a few cases of esotropia, as will be shown farther on, in which it would not be correct to do anything primarily but advance the externi and depress their planes of rotation.

The two effects that can be accomplished by shortenings and advancements are an increase of tonicity and a change of the plane of rotation. The former must always be accomplished, while the latter should be accomplished in some cases, but avoided in others. The two effects that can be accomplished by partial tenotomies are diminution of tonicity and a change of the plane of rotation. The former must always be attained, while the latter must be accomplished in some cases, but avoided in others.

Before operating on any case of esotropia it must be decided whether the tonicity alone shall be altered, or whether, in connection with altering the tonicity, the plane of rotation shall be changed. To alter only the tonicity of the muscles, when their planes also should be changed, would be to fail to cure the case. In all cases in which the deviating eye is not totally blind it may be known beforehand just what kind of an operation should be done. If the deviating eye is totally blind, there can be no indication for a change of plane, and all that should be done for such a case would be to alter the tonicity.

The operative treatment of uncomplicated esotropia should be applied primarily to the deviating eye, with the view of leaving some of the error to be corrected by means of operations on the other eye. The externus of the deviating eye should be well advanced, straight-forward, so as to increase its tonicity without changing its plane of rotation, and at the same time a central partial tenotomy of the opposing internus should be done, the operator always being careful to leave uncut a sufficient number of fibers above and below to act as stay-cords. By this partial tenotomy the tonicity is reduced, but the plane is not changed. These two operations, done at the same time, will usually enable the patient to fix with this eye, the other eye now becoming slightly crossed.

After an interval of two or more weeks a central partial tenotomy of the internus of the good eye should be done, with the view of lessening its tonicity without changing its plane. If it appears that the effect of this partial tenotomy is not enough, the externus of this eye should be shortened, straight-forward, at once; or, if a still greater effect is needed, this muscle should be advanced straight-forward. In either case the tonicity of the muscle would be increased, but its plane would not be changed. At the time the partial tenotomy is done, if there is

doubt as to whether enough has been accomplished, nothing more should be done at that time. Later, if found necessary, the externus should be shortened.

In all uncomplicated cases of esotropia that cannot be cured or greatly helped by non-operative means, three operations—advancement of the externus, a partial tenotomy of the internus of the deviating eye, and (a little later) a partial tenotomy of the internus of the good eye—should be done; and a fourth operation—shortening or advancement of the externus of the good eye—may be demanded. If these operations are carefully done, the result should be a restoration of the power of binocular single vision.

If esotropia is complicated by a hypertropia of one eye and catatropia of the other and there is no cyclotropia, the operations for the cure of the esotropia should be done as if there were no complication—that is, by altering the tonicity of the lateral recti in such a way as not to make the slightest change in their planes of rotation. Later, or even simultaneously, the vertical error should be treated as will be set forth in connection with the study of the vertical deviations.

If esotropia is complicated by cyclotropia, the operations done for altering tonicity should be so done as to change the planes of rotation also. In esotropia with plus cyclotropia, but no hypertropia, the partial tenotomies of both interni should be marginal, including all of the lower and central fibers, and equal in extent, leaving uncut the upper fibers, thus altering tonicity and elevating the planes of rotation; and the shortenings or advancements, equal in extent, of both externi should be done so as to give them a lower attachment, unless it is shown by tests that the marginal tenotomies of the interni, which should always be done first, have fully corrected the plus cyclotropia. If the plus cyclotropia has been cured by the marginal tenotomies of the interni, the remaining part of the esotropia should be treated by straight-forward advancements or shortenings of the externi.

If esotropia is complicated by plus cyclotropia of both eyes and right hypertropia and left catatropia, the following plan of operating should be adopted: First, an advancement of the externus of the right eye so as to lower its plane of rotation. This would counteract, in part, the esotropia, the cyclotropia, and the right hypertropia; for the muscle, by means of its new attachment, would pull the eye toward the temple, draw it down, and tort it in. The second operation should be done on the internus of the left eye, and it should be a partial tenotomy, including all the lower and central fibers and leaving uncut only the fibers at its upper margin. By a reduction of the tonicity of this internus, the externus will draw this eye toward the temple,

while the upper uncut fibers of the internus will pull the eye up and tort it in. Thus the esotropia will be further corrected, and the plus cyclotropia and the catatropia will be wholly, or in greater part, corrected. Any remaining esotropia must be counteracted by a central partial tenotomy of the right internus, and, if necessary, a straightforward advancement of the left externus, for the reason that if by the first two operations the vertical heterotropia and the plus cyclotropia have been cured, the remaining esotropia would be uncomplicated and should be so treated; and for the further reason that should there still remain some of both complications after the first two operations, elevation of the plane of the right internus would increase the hypertropia while lessening the plus cyclotropia, and lowering the plane of the left externus would increase the catatropia, while lessening the plus cyclotropia. In such a case, therefore, the planes of rotation of the right internus and the left externus should not be changed, although it may be necessary to alter their tonicity. Any vertical heterotropia and plus cyclotropia remaining after the first two operations, should be corrected by a partial tenotomy of the superior rectus of the right eye, including all of its nasal fibers and as many of its central fibers as might be necessary. Should there still remain some of the left catatropia and plus cyclotropia, a partial tenotomy of the left inferior rectus should be done, including all the temporal fibers and as few as possible of the central fibers. The six operations performed in the order named, and done with proper care, should cure the worst case of this kind. The only remaining operations that should be done in such a case are: advancement of the nasal margin of the right inferior rectus and advancement of the temporal margin of the left superior rectus, the indication for which would be some remaining plus cyclotropia with right hypertropia and left catatropia. The first four operations usually accomplish everything that could be desired. To ignore the vertical heterotropia when complicated by plus cyclotropia, or to ignore the plus cyclotropia when it is the only complication, in operating for esotropia, is to fail to cure the patient.

By far the most troublesome cases of esotropia—the incurable cases, under the old methods of operating—are those complicated by plus cyclotropia and double hypertropia. The primary deviation is in and up, and the eye is torted out; likewise, the secondary deviation is in and up, and the eye is torted out. In these cases the double hypertropia and the plus cyclotropia are both caused by over-action of the inferior obliques, while the whole of the esotropia is caused by over-action of the two interni, a large part of this over-action of the interni being in the nature of a spasm. In some of these cases a division

of the two inferior obliques will cure the double hypertropia, the plus cyclotropia, and the esotropia; and this was doubtless the operation done by the quack, Taylor, referred to in an earlier part of this section. The author has done this operation sometimes near its origin, and sometimes at its attachment to the sclera, and with gratifying results. These cases always carry their heads high, but they should be carefully studied otherwise than as to the pose of the head. In the more aggravated cases of this character, cutting completely across the inferior obliques by means of a Graefe knife, being careful not to injure the infraorbital vessels and nerves, is probably the best method of procedure; but in milder cases cutting only the anterior fibers at the insertion is safer and better. If the inferior obliques are not to be cut in these cases, the first two operations should be done on the superior recti at the same time, and should consist of a division of all the nasal and central fibers of each, leaving uncut only the temporal margins. These operations would lower the two eyes, and the uncut temporal fibers would tort both eyes in. In some of these cases these two operations go far toward curing, not only the double hypertropia and the plus cyclotropia, but also the esotropia. The next two operations, to be done at the same time or with a short interval between, are advancements of both externi. These operations should be done to increase the tonicity of these muscles, so as to counteract the esotropia, and to lower their new attachments, so as to still further correct the double hypertropia and the plus cyclotropia. Usually nothing else will have to be done. Should there remain, after these four operations, some of the double hypertropia and plus cyclotropia, the nasal margins of both inferior recti should be advanced. Any remaining esotropia should be corrected by a central partial tenotomy of one or both interni, in such a way as not to change the plane of rotation; for to elevate the plane would be to increase any uncorrected hypertropia, while lessening any uncorrected plus cyclotropia.

Since minus cyclotropia, as a complication of esotropia, is so very rare, it is only necessary to say that, in operating on the interni, their planes should be depressed; and in operating on the externi, their planes should be elevated, this being the very reverse of what should be done when there is plus cyclotropia.

If a patient should be unwilling to undergo all the operations that might be necessary for correcting his comitant esotropia, he may have the reflex nervous symptoms relieved by submitting to one operation —namely, a partial tenotomy of the internus of the fixing eye. This would relieve the nervous tension of the externus of this eye, without

risk of interfering with the comitant movements of the two eyes, but it would not correct the esotropia.

In speaking of advancement operations no special one has been named. I would not be true to my convictions, nor would I be just to the reader without making this declaration: The best of all advancement operations, therefore the only one that should be done, is the "flat advancement" without severing the tendon, devised by Lagleize. A horseshoe incision, with the convexity toward the cornea, should be made through the conjunctiva and capsule of Tenon, from a point well in advance of the tendon attachment, backward, over the muscle to be advanced, sufficiently far to expose that part of the muscle through which the loop of the suture must be passed. The assistant must hold this flap out of the way by means of a forceps. The operator then passes a large strabismus hook beneath the tendon, and draws it well up against the insertion of the tendon. Next he passes a second large hook beneath the tendon and carries it backward beneath the belly of the muscle to a point beyond where he expects to pass the loop of suture. He now places the second hook in the hand of the assistant, who gently lifts the muscle away from the globe. With the first hook the operator steadies the eye while passing the suture through the muscle, which he may do in one of two ways: (1) He may take the muscle part of the stitch with only one of the two needles with which the suture is armed, by passing it through the muscle near one border and bringing it out at a point directly opposite, near the other border. Drawing the suture after the needle thus passed places the loop beneath the belly of the muscle. Or (2) he may pass one needle beneath the muscle and force it through near the far border, and then pass the second needle through the near border, from beneath, at a point directly opposite the puncture of the other needle. Drawing the suture after the two needles places the loop beneath the belly of the muscle, as if it had been taken with one needle, as described in (1). This loop must always be just as far behind the insertion of the tendon as the later scleral stitches shall be in front. The muscle part of the suture having been passed, the two hooks should be removed. The next step of the operation is the passing of both needles through the anterior margin of the capsulo-conjunctival flap. The operation must be completed without cutting the tendon. To enable him to pass easily the scleral stitches, the operator fixes the eyeball by firmly grasping, with fixation forceps, the exposed tendon at its insertion, and then passes first one needle and then the other deep into, but not through, the sclera, at points just as far in advance of the tendon insertion as the loop is behind it. The scleral stitches are to be neither

higher nor lower than the two points of passing of the muscle part of the suture, if the rotation plane of the muscle is not to be changed. The needles should now be passed through the two holes of the Price suture plate, after which they should be removed. In tying the surgeon's knot on the silver plate, the muscle is carried over its attachment until that part through which the loop was passed is at the line of the two scleral punctures, and it is kept there by the completion of the knot. The capsulo-conjunctival flap completely covers the operative field by having been included in the suturing. The stitch must be allowed to remain seven days.

If the rotation plane of the muscle must be changed, the scleral punctures must be made in the direction indicated in any given case.

There is no advancement operation that will compare with the "flat advancement" operation of Lagleize, in the case with which it is done, in simplicity, and in safety; but even this operation should be done only when more effect is needed than can be gotton from the simpler and safer operation of tucking, or folding, or shortening.

Muscle shortening. This operation,* rather than advancement, should be done in nearly all cases of heterophoria, and in many cases of heterotropia, in which the indication is to increase the tonicity of the muscle. Not only can this operation alter the tonicity of the muscle, but it can also be done so as, at the same time, to change its plane of rotation. Its advantages over the advancement operation are three: First, it is easier of accomplishment, though a little more painful; second, its plane of rotation is less likely to be changed when there is no indication for changing it; third, the stitch is not so likely to cut its way out, and if it does so, or if the knot should become untied, the case would be no worse than before the operation; whereas, if either of these accidents should happen to an advancement, other than the Lagleize, before adhesion has formed, the recession of the muscle might be farther back than its original attachment. However, in some cases of heterophoria, in which the indication is to increase the tonicity, the muscle attachment is so far back, or the muscle itself is so small, that an advancement must be done.

The shortening operation for simply increasing the tonicity of the muscles is done as follows: Lids must be widely separated with the speculum. The conjunctiva must be seized with the forceps, so as to be thrown into a fold parallel with the corneal margin, behind the tendon insertion; and this conjunctival fold, if the muscle be an externus or an internus, must be cut with the scissors a little below the

* See *Ophthalmic Record,* March, 1893, in which it was first described.

lower border of the muscle; but if it be a superior or inferior rectus, the cut must be to the nasal side of the muscle. Through this cut the capsule of Tenon is grasped and cut in line (meridionally) with the conjunctival cut. Through the opening thus made, one of the large strabismus hooks is passed beneath the muscle and drawn forward until stopped by the attachment of the tendon; then, through the same opening, the second large hook is passed beneath the belly of the muscle and carried backward, at the same time lifting the muscle from the sclera, so as to show the extent of the possible shortening. If the opening in the conjunctiva and capsule, by being too small, should stop the second hook too soon, it should be enlarged toward the equator by a cut or two with the scissors. Having already armed the number seven silk with two needles, the operator places one of them in the needle holder, and, passing it through the cut beneath the muscle, forces it through the upper border of the tendon, close to the sclera (if an internus or an externus, but the outer border if a superior or inferior rectus), and brings it out at once through the capsule and conjunctiva. While doing this the tendon is held up by the first hook and the needle is passed between this hook and the sclera. No other puncture will have to be made with this needle, but it should remain on the suture so as to facilitate the passing of that end of the suture through one of the holes of the Price suture plate later. The first hook remaining under the tendon and still held by the operator, the assistant is directed to pass the other hook as far back beneath the muscle as possible, at the same time lifting the muscle well from the sclera. The operator, with the second needle in the holder, passes it through the opening beneath the belly of the muscle as far back as he wishes, when he forces it through the muscle, then through the capsule and conjunctiva, so that a line connecting this and the first puncture shall be parallel with the plane of rotation of this muscle. The suture is now drawn on so as to make the thread disappear beneath the muscle. The second needle is again placed in the holder, and the operator passes it through the conjunctiva, capsule, and the other border of the muscle, bringing it out through the cut in the conjunctiva and capsule. The third puncture is so made that the loop of thread passing from the point of the second puncture to it, and lying on the conjunctiva, shall be parallel with the equator of the eye. Now the assistant's hook may be removed. The surgeon again places the second needle in the holder and passes it through the cut beneath the tendon, which he still lifts with his own hook, and forces it through the other border of the tendon close to its insertion, and brings it out through capsule and conjunctiva, so that a line connecting the first puncture and this,

the fourth, shall be parallel with the corneal margin, and the line from the third to the fourth puncture shall be parallel with the plane of rotation. Drawing on this end of the suture, that part of it between the third and fourth punctures disappears beneath the muscle. The operator's hook is now removed, and the two needles, after being made to carry the two ends of the suture through the holes in the silver plate, are also removed. It only remains to tie a surgeon's knot over the plate, drawing sufficiently hard to bring forward that portion of the muscle lying beneath the loop which rests on the conjunctiva, until it rests in contact with the tendon at its insertion. The knuckle of muscle, capsule, and conjunctiva thus made demands no attention, since, in the course of a few weeks, it disappears by absorption atrophy. The patient will complain some at the first two passages of the second needle, and also of the drawing brought about by tying the knot. The after-treatment is the same as that for partial tenotomies.

If a shortening is to be done so as not only to alter the tonicity of the muscle, but also to change its plane of rotation, the operation differs from that already described only in the making of the four punctures while placing the suture. Let the condition to be relieved be an asthenic exophoria complicated by a plus cyclophoria, in shortening an internus it should be that one belonging to the cataphoric eye, provided there is a vertical error, otherwise both interni should be shortened. The first needle should be passed as nearly as possible through the upper border of the tendon; the second needle should make its first puncture through the muscle below the plane bisecting it, while its second puncture should be made as near as possible to its lower border. The third puncture with the second needle should be made between the first puncture and the plane bisecting the attachment of the tendon. Thus it will be seen that the first and fourth punctures are above the natural plane of rotation, while the second and third punctures are below this plane. In tying the knot, the lower border of the muscle is carried upward, and in this way the muscle is given a new and high attachment, and thereby the plane of rotation is correspondingly elevated.

If the external rectus must be shortened to cure an asthenic esophoria complicated by a plus cyclophoria, the position of the punctures should be reversed; for in such a case the plane of rotation must be depressed by the creation of a lower attachment, and both externi must be thus operated upon. If there is also a hyperphoria, this operation should be done only on the externus belonging to the hyperphoric eye.

If the superior rectus is to be shortened to cure an asthenic cata-

cyclophoria of the eye to which it belongs, the first and fourth punctures must be to the outer side of its old plane of rotation, while the second and third punctures should be on the inner side of this plane. Tying the knot will create a new attachment farther toward the temple than the original one. Thus the plane of rotation is shifted out. Just the reverse must be true of the punctures if they are to be made on the inferior rectus with the view of curing an asthenic hypercyclophoria of the eye to which it belongs. This would shift its point of attachment toward the nose, carrying the plane of rotation with it.

Partial marginal shortenings may be done for the relief of cyclophoria when there is no special indication for altering the tension of the whole muscle. In such an operation, all the needle punctures should be made on the same side of the muscle plane. To illustrate: There being but little exophoria, the existing plus cyclophoria may be cured by changing the plane of both interni without greatly increasing the tension of these muscles. For the accomplishment of this the conjunctival and capsular cut must be at the upper border of the muscle; the needles must be passed the four times entirely in the upper half of the muscle and tendon; and the space between the insertion of the tendon and the loop of the suture must not be any thing like so great as in a shortening of the whole muscle. Tying the knot over the suture plate folds only the upper part of the muscle, the power of this part being thereby increased. The same operation should be done on the internus of the fellow eye.

If the partial marginal shortening, to cure a plus cyclophoria, is to be done on the externi, the lower margin of the muscle and tendon is the part to be folded, and the effect should be divided between the two externi. If, for the same condition, the operations are to be done on the superior recti, the suture must be taken in the temporal margin of each; if on the inferior recti, the inner margins only must be folded. But better and easier than partial marginal shortenings would be marginal advancements.

In exaggerated esotropia, Edward Jackson (see *infra*) operates on the nasal-central fibers of the superior and inferior recti, and his reports have been very favorable. This double operation on the vertically-acting muscles would be justifiable only when the esotropia is simple; that is, unassociated with a hypertropia and plus cyclotropia. With these complications, only the nasal-central fibers of the superior rectus should be cut, and nothing at all should be done to the tendon of the inferior rectus of that eye. Even in these exaggerated cases the operation on the internus should not include its entire attachment. To supplement the effect of operations on the internus and on the

superior and inferior recti, one or both as indicated, the externus should be either shortened or advanced.

Hopeless esotropia. Already a word of warning has been sounded in connection with those cases of esotropia who have equally good vision in the two eyes. Almost without exception, these are cases of antipathy to binocular single vision—cases that have never seen singly with the two eyes, and can never be made to have binocular single vision, for the anatomic reason of faulty brain-cell connection. In these cases the false image cannot be made to fuse with the true by any sort of prism manipulation. In such cases operations are always attended by the danger that very troublesome diplopia may result, whereas before the operations there was no diplopia. The best that can be done in these cases is to partly correct the disfigurement, and the patient should be so informed. Even in this respect such patients are rarely satisfied with the results, hence the need for fortifying against complaints.

EXOTROPIA.

This condition, the opposite of esotropia, shows itself in such a deviation of one eye that its visual axis, instead of intersecting the visual axis of the fixing eye at the point of view, deviates from it. It is generally taught that myopia is one of the factors in its production. As taught in a previous section, pseudo-exophoria manifests itself only in the near; so it would appear that myopia, on which pseudo-exophoria depends, could have nothing to do directly in the causation of an exotropia that shows itself when the point of view is in the distance. Myopia does cause exotropia to be greater in the near than in the far. The true cause of exotropia is intrinsic exophoria. In a myope the exotropia first shows itself in the near, when the pseudo-exophoria is grafted on the intrinsic exophoria, the two together producing the exotropia. Beginning in the near, the exotropia will show itself in the distance also, for the reason that the mind, learning to disregard, in near work, the images on the retina of the deviating eye, becomes able to suppress the images of distant objects, and this suppression leads to the conversion of the exophoria into exotropia. In this way myopia does contribute to the production of exotropia. An early cure of the pseudo-exophoria, by a full correction of the myopia, prevents an exotropia in the near that does not exist in distant vision, and the intrinsic exophoria may remain unchanged through life, because the sharper images of distant objects through the myopic lenses, lead the guiding sensation to call more earnestly on the fusion faculty of the mind for fusional activity of the right and left third basal centers. If

myopia were as common as hyperopia, exotropia would be found as often as esotropia; for intrinsic exophoria exists in fully as many cases as does intrinsic esophoria.

Exotropia may depend only on the excessive strength of the externi as contrasted with the interni. This difference in relative strength may be due to hyper-development of the externi or subnormal development of the interni, or to the fact that the externi have a more advantageous attachment to the globe than have the interni. Associated with either the one or the other of these conditions, there may be a deficiency in the third conjugate innervation center, causing an exotropia in the near which gradually grows to exotropia for distance. While the chief cause—the sole cause in most cases—may be in the excessive strength of the externi, the obliques may also enter into the causation, and that, too, without there being any imbalance of the obliques. If the obliques are hyper-developed, or if they are attached too far behind the equator, or if they are too short and tense, they will help the too strong externus to turn the eye out. If, in any case of exophoria, disease or injury should greatly reduce the vision of one eye, it will become exotropic in time. In anisometropia, if there is exophoria, the worse eye eventually will turn outward, in many cases. A congenitally low state of vision in one eye, when there is exophoria, will favor its transformation into exotropia. It is doubtful if "antipathy to binocular single vision" is as often a cause of exotropia as it is of esotropia, if ever.

The chief cause of many cases of exotropia has been traumatism; and, unfortunately for science, it has been operative traumatism. "Straightening crossed eyes in a minute" has most often resulted in a perpetual out-turning. But in the past, complete tenotomies of the interni for esotropia, performed by both general and ophthalmic surgeons, because they had been taught to do so by such masters as Dieffenbach and Graefe, resulted often, in a year or two, in an exotropia that was not comitant. Such a disaster has happened to every surgeon who has made many complete tenotomies of the interni, even when he was most careful not to cut the check ligaments. It is true that exotropia has not followed all the complete tenotomies of the interni that have been made, else surgeons would have ceased, long ago, to attempt thus to relieve patients of one deformity simply to bring on them another, even more objectionable. Thanks to the long and strong insistence of Landolt, that advancement should supplant tenotomies, the days of complete tenotomies of the interni are numbered. Even Panas' operation cannot long delay the total abandonment of complete

tenotomies for the relief of esotropia or any other form of heterotropia. Then no case of exotropia will result from surgery.

While comitant exotropia may show itself in only one eye, it is, nevertheless, a binocular trouble, which should not be forgotten at the time treatment is instituted. Exotropia always begins later in life than esotropia. Exotropia may be alternating early in the history of a case, but it soon becomes the fixed habit of one eye, usually the one that has conditions most favorable to mental suppression of images —a habit that is acquired by exotropes as well as by esotropes.

The complications of exotropia are errors of refraction (myopic refraction helps to cause exotropia); double hypertropia and double catatropia; hypertropia of one eye and catatropia of the other; and symmetrical or non-symmetrical cyclotropia. Treatment of the complications must constitute a part of the treatment of the chief condition, and, for this reason, they should not be ignored in any case.

The amount of exotropia can be determined readily, by any one of the methods resorted to for measuring esotropia, by a reversal of every step.

Symptoms. The symptoms of exotropia are objective and subjective. The only objective symptom is the disfigurement, which is greater or less, in proportion to the extent of the outward turning. Amblyopia, in many cases, is the only subjective symptom; and this—in some cases, at least—has been acquired by the power of mental suppression. Exophoria is attended, practically always, by reflex symptoms, as already shown; but reflex symptoms are rare in exotropia. The reflex symptoms found in a case of exotropia are due either to the nervous tension of the internus of the fixing eye or to some one or more of the complications. Exotropes who have been made so by complete tenotomies of the interni are more liable to show reflexes, and for the reason that the out-turned eye cannot move comitantly with its fellow. It is the generation of the excessive impulse—the unbalanced impulse—to force comitant movements that cannot be forced, which brings about the reflex disturbances. To illustrate: Suppose that the right internus has been cut, resulting in a non-comitant exotropia. When the eyes are made to move to the right, there must be abnormal action of the fourth conjugate center; for the left internus, being opposed by an uncrippled externus, will require a greater impulse for a certain movement of its eye to the right than will the externus of the right eye, which is opposed by a crippled internus. It is the fourth conjugate brain-center that effects this rotation, and it cannot act normally under such a condition. In such a case, when the eyes are rotated toward the left, it must be through

the fifth conjugate brain-center, which will attempt the impossible task of making the crippled right internus move its eye comitantly with the fellow eye whose externus is not crippled. The impossibility of accomplishing the task does not prevent the brain-center from undertaking it. Disturbance of one brain-center can excite sympathetic disturbance in any other brain-center.

One of the worst neurotic conditions that the author has ever seen was in a patient who had a non-comitant exotropia which had resulted from a complete tenotomy of his right internus, performed many years before. His case was diagnosed as an organic brain disease, and he was treated accordingly for two or more years without improvement. That his troubles were all reflex, and that the cause was his non-comitant exotropia, cannot be doubted, for he recovered quickly after the enucleation of his exotropic eye, which operation was done at his own earnest solicitation; he even demanded that it should be done, believing, as he did, that this was his only chance. His belief that his troubles were referable to the condition of his right eye was based on temporary relief which he experienced two years previously from an advancement operation on the right internus, performed by the author, with an incomplete result as to position and movement. Later, an operation was done on the right superior rectus for a complicating hypertropia, with renewed relief of some of the symptoms that had again become prominent. Later, the author expected, and promised, to bring the right internus, atrophied as it was, still further forward. The symptoms became aggravated again, and the patient returned for the promised operation. A colleague, J. A. Witherspoon, of Nashville, skilled in neurology, was called in consultation. The doctor pronounced the case one of organic brain disease, the author agreeing with him. No other operation was attempted. The patient was placed entirely in the hands of the consultant, who treated him without results. In a few months the patient was induced to go to a sanitarium, where he remained for nearly two years without any marked change in his condition, either for better or worse. It was while there that he insisted on the operation of enucleation, which was done. He has remained well from that time until now, a period of about fifteen years.

The above case is thus fully reported to emphasize the point that a comitant hetertropia of one kind should never be converted into a non-comitant heterotropia of another kind, to avoid which one should be careful never to do a complete tenotomy of any rectus muscle for any condition.

In this connection it may be said that, in all probability, John

Dunn, or the late Hunter McGuire, of Richmond, Va., was the first operator to enucleate one eye in which there was good vision, to relieve the patient of severe nervous symptoms caused by what was considered a hopeless muscle imbalance. The operation cured the patient. This case has not been reported.

Another case may be referred to also, somewhat like the two preceding cases as to results, though the method of obtaining them was unlike that resorted to in the other cases. This case was that of a young lawyer who suffered so much with his head and eyes that he contemplated giving up his profession, having failed to get relief from cylinders which he needed, from prisms which he did not need, and from ceiling-to-floor and wall-to-wall exercise, which, for some reason, he was unable to do for even one minute without suffering. There was no heterophoria, but the muscles were "balanced in weakness," as shown by the fact that his abduction was two degrees; his adduction, less than ten degrees; his sub-duction and super-duction one degree. The vision of his right eye was $\frac{20}{XX}$; that of the left eye, $\frac{20}{XL}$. Every means that had been suggested by any one of the several ophthalmic surgeons whom he had consulted had been tried, and failure had resulted from all. At last the author advised him to have his left eye rendered useless. He consented, and the left lens, already slightly opaque, accounting for the reduced vision, was carefully needled, so as to render it more densely opaque without effecting its solution. The comfort which he had been seeking came as a result of this operation. It has been twelve or more years since the operation was done, and there has been no return of his symptoms. Nothing else than making the one eye blind, or removing it, could have cured him, except the shortening of all the recti muscles, and it is doubtful if that would have done it. These shortenings the author would have advised if the lens in his left eye had been perfectly transparent and vision had been good.

These three cases are reported here, though not properly connected, because of the results that followed so radical operations, after all other means had failed. These three patients, operated on by three different men, would agree that it is better to go through life with only one eye than to have two eyes that would be a constant source of suffering. If relief can be obtained short of sacrificing one eye, so repulsive an operation as enucleation should be avoided.

Treatment of exotropia. The correction of myopia early in the history of an exotropia—that is, when there is exotropia in the near, but

none in the far—by removing the pseudo-exophoric factor, may correct the exotropia, reconverting the exotropia into an intrinsic exophoria. But the correction of the exotropia by means of the concave lenses is not a cure, in the proper sense; the intrinsic exophoric factor must also be removed, and this can be done, in such a case, only by partial tenotomies of the externi or by shortenings or advancements of the interni, or by both.

In simple uncomplicated exotropia at least three operations should be performed. Two operations on the deviating eye should be done first. One of these should be a partial tenotomy of the externus, so done as to lessen its tonicity without changing its plane of rotation—a central partial tenotomy; and at the same time the opposing internus should be either shortened or advanced, and in such a way as to increase its tonicity without changing its plane—a straight-forward shortening or a straight-forward advancement. At any time after one week, a partial tenotomy of the externus of the fellow eye should be made, and in such a way as to lessen its tonicity without changing its plane—a central partial tenotomy. If these three operations do not properly relate the eyes, a fourth operation should be done, at any time after two to four weeks. This operation should be a shortening or an advancement of the internus of the good eye, and it should be so done as to increase its tonicity without changing its plane—a straight-forward shortening or a straight-forward advancement. A very slight simple exotropia may be cured by central partial tenotomies of the two externi, performed at the same time; but most cases will require three, if not four, operations. If these operations have been performed in the order and after the manner set forth above, the operator need have no fear that his case, which was comitant exotropia before the operations, will become non-comitant esotropia later; nor need to have any fear that a torsioning of the eyes will result. In exotropia of medium or high degree, the operation on the weak interni must be an advancement, for a shortening cannot produce enough effect.

An exotropia complicated with a double hypertropia, a double catatropia, or a hypertropia of one eye and a catatropia of the other, would require for its relief the same kind of operations as if there were no complication—that is, the partial tenotomies of the externi should be central, so as to lessen tonicity without a change of plane; and the shortenings or advancements of the interni should be straight-forward, so as to increase tonicity without a change of the plane of rotation. In the course of the treatment, the vertical heterotropia should be

relieved in the manner to be shown in the study of hypertropia and catatropia, uncomplicated by cyclotropia.

If exotropia is complicated by plus cyclotropia only, the order of operating, as well as the method, should be changed. The two operations to be done first, and in immediate succession, should be performed on both externi, and should consist of a marginal tenotomy of each, the cut including the upper and central fibers, the lower fibers to remain intact. These operations would lessen the tonicity of both externi, and would lower their planes of rotation, so that, in their new relationship, they would tort the eyes in. This change of plane would also cause a double cataphoria. The operative effect on the two muscles should be as nearly equal as possible, so as to tort both eyes in alike and depress them equally. After these two operations, if some of the plus cyclotropia, as well as some of the exotropia, should remain, both interni should be shortened or advanced equally, and in such a manner as to elevate their planes of rotation. The amount of increase of tonicity and the extent of the elevation of the planes would have to be gauged according to the best judgment of the operator. The end in view should be perfect control of the visual axes and the paralleling of the vertical axes with the median plane of the head. If the two marginal tenotomies should correct the whole of the plus cyclotropia, the remaining exotropia should be corrected by straight-forward shortening or advancement—first, of the internus of the deviating eye; and later, if necessary, of the internus of the good eye.

If exotropia is complicated with plus cyclotropia, right hypertropia, and left catatropia, the operations on the lateral recti should be done so as to alter their tonicity and change their planes of rotation, the latter only up to the point of a full correction of the plus cyclotropia. The operations should be done in the following order, with two or more weeks intervening: The first operation should be a marginal partial tenotomy of the externus of the hypertropic eye, including the upper and central fibers. The effect of this would be (1) to lessen its tonicity, so that the internus might draw the eye in; (2) lowering the plane so as to tort the eye in, to counteract the plus cyclotropia, and at the same time (3) turn the eye down for counteracting the right hypertropia. The second operation should be a shortening or an advancement of the left internus, so as to increase its tonicity and elevate its plane; and, that this may be done, not over half of the correction of the main error and its complications should be attempted in the first operation. The effect of the second operation would be (1) to increase its tonicity so as to enable it to draw the eye in; (2) to

tort the eye in, by means of the elevation of the plane, so as to counteract, if possible, the remaining plus cyclotropia; and (3) to elevate the eye, to still further—and, if possible, entirely—relieve the remaining part of the left catatropia. If, for the further relief of the exotropia (whether or not there may have remained from the first two operations some of the plus cyclotropia), it becomes necessary to operate on the internus of the right eye and the externus of the left eye, each of these operations would have to be done so as to alter tonicity without changing the plane of rotation—that is, the shortening or the advancement of the right internus would have to be straightforward, and the partial tenotomy of the left externus would have to be central. The reason for this is clear: To elevate the plane of the right internus would help to correct any remaining plus cyclotropia, in itself desirable, but this would also elevate the eye—a thing not to be desired; to depress the plane of the left externus would correct any remaining plus cyclotropia, in itself desirable, but it would depress still further the eye that is already too low.

It is so very rare that a minus cyclotropia is found complicating an exotropia, it is only necessary to say that, when it does exist, both the order of operating and the method of doing each operation, looking toward a change of the muscle plane, should be the reverse of what has been advised when plus cyclotropia is the complication.

When exotropia is complicated by a double hypertropia and plus cyclotropia, it is probable that both complications are caused by the inferior obliques, and that these muscles have also entered largely into the causation of the exotropia. The operation most plainly indicated is a division of the inferior oblique of both the deviating eye and the fixing eye. If it were possible, in doing these operations, to leave some of its fibers uncut, it would be better. But a hook and scissors cannot be used, and the division must be effected by passing a Graefe knife above and beyond the muscle and between its origin and the course of the infra-orbital vessels and nerve, with the cutting edge of the knife looking toward the orbital floor, then bringing the knife down, dividing every structure between it and the orbital floor. The author will say that he has done this operation on only a few cases, and the results were highly satisfactory. He would not hesitate to do it again in cases so well marked. To divide the anterior fibers of the inferior oblique at its insertion would lessen the plus cyclotropia and the hypertropia but it would increase the exotropia.

If the case is not sufficiently exaggerated to justify a complete division of the inferior obliques, or if these have been divided. but some of the main error with both of its complications remains, a marginal

tenotomy of both externi should be done, including the upper and central fibers. This would lessen their tonicity, so as to allow the eyes to be drawn toward each other by the interni, and the lower uncut fibers would depress the eyes and would tort them in. To make shortenings or advancements of the interni with the view not only of increasing their tonicity, but also of changing their planes of rotation would be wrong; for elevating these planes would raise the eyes still higher, while counteracting the plus cyclotropia—hurtful in one result, while helpful in the other. It is clear, therefore, that, in such a case, if the tonicity of the interni must be increased to still further correct the exotropia, the shortenings or advancements should be straightforward.

At the meeting of the American Medical Association in Atlantic City, N. J., in 1900, L. Webster Fox, of Philadelphia, read before the section of Ophthalmology a paper entitled "A Simple Operation for Divergent Strabismus." He stated in this paper that he had put to a test the various accepted methods for correcting this error, and that he had noted the difficulties and many failures in his own practice, such as had been experienced by others. This led him to devise the method which he wished to describe, and for the reason that, through a period of eight years, it had given him satisfaction. It consisted of a complete tenotomy of both externi, and the incision of an eliptical fold of conjunctiva and capsule of Tenon over the tendon of one internus, sometimes of both, and then stitching the edges together in a vertical line. On this operation the author's comment would be *never make a complete tenotomy.*

The form of exotropia that most urgently demands relief is the non-comitant exotropia which has resulted from complete tenotomies for esotropia. In these cases the externi, which were never possessed of too much intrinsic strength, should not be even partially cut, but the whole effect should be accomplished by advancement of the internus that had been allowed to retract too far. In these cases all the complications must be considered, and the advancements should be governed accordingly.

HYPERTROPIA AND CATATROPIA.

These conditions practically always exist as complications of either esotropia or exotropia, and not infrequently are associated with cyclotropia. Hypertropia may be double, and catatropia may be double, of course, alternating, or there may be a hypertropia of one eye and a catatropia of the other, also alternating. If there is double hypertropia without cyclotropia, the error is caused by the conjoined action

of the superior recti and the inferior obliques, both of which elevate the eye, while the in-torting action of the superior rectus is counteracted by the out-torting action of the inferior oblique.

If there is double hypertropia with minus cyclotropia, the chief factors in its production are the superior recti, aided, possibly, by interni whose attachments are too high.

If there is double hypertropia with plus cyclotropia, the chief factors are the inferior obliques, aided, possibly, by externi that are attached too high.

Double catatropia, if caused by both the inferior recti and the superior obliques, will show no cyclotropia; if caused by the inferior recti alone, or with the aid of interni that are attached too low, there will be plus cyclotropia also; if caused by the superior obliques alone, or with the aid of externi whose attachments are too low, there will be minus cyclotropia also.

When there is hypertropia of one eye with catatropia of the other, there will be no cyclotropia, if the hypertropia is caused by the conjoined action of the superior rectus and the inferior oblique, and the catatropia is caused by the united action of the inferior rectus and the superior oblique.

If the hypertropia of the one eye is caused by the superior rectus alone, or with the aid of a too high internus, there will be minus cyclotropia; and if the catatropia of the other eye is caused by the inferior rectus alone, or with the aid of too low internus, there will be plus cyclotropia—the two eyes together would have parallel cyclotropia.

If there is hypertropia of one eye with catatropia of the other, and the complication is plus cyclotropia of both eyes, the cause of the hypertropia is the inferior oblique, and the cause of the catatropia is the inferior rectus; or, if the complication is minus cyclotropia, the cause of the hypertropia is the superior rectus, and the cause of the catatropia is the superior oblique.

The cause of the vertical heterotropias is in the muscles that are concerned in elevating and depressing the eyes, aided in some cases by the lateral muscles that are attached too high or too low. For the first year or two the want of harmony between these muscles is shown by some form of vertical heterophoria, which, especially when associated with some form of imbalance of the laterally acting muscles, becomes transformed into a vertical heterotropia at the same time that the lateral heterophoria becomes transformed into lateral heterotropia. Hypertropia and catatropia rarely exist alone. They are

comitant in character, except when they are the result of operations or caused by paralysis.

The disfigurement of the individual is the objective symptom; and the subjective symptoms are those already mentioned in connection with the study of the lateral heterotropias. Reflex neuroses are not often connected with the comitant form; but when they do exist their cause is abnormal nervous tension of the weaker muscle of the fixing eye. But the non-comitant hypertropia or catatropia—nearly always the latter, for the reason that a complete tenotomy of a superior rectus for a hyperphoria is more often done than a complete tenotomy for a cataphoria—often causes severe reflexes; besides, a non-comitant catatropia, resulting from a complete division of a superior rectus for a hyperphoria, in an adult, is always attended by diplopia. At that age mental suppression is impossible.

These errors can be measured more easily by the phorometer than by any other method, but the perimeter and the tape methods (the graduated tape to be held vertically) can be resorted to.

Treatment of vertical heterotropia. In the discussion of the treatment of esotropia and exotropia it has been shown that, when hypertropia and catatropia are the only complications, each condition must be treated as though the other did not exist—that is, every offending muscle must have its tonicity altered without a change of plane. In the same manner must uncomplicated vertical heterotropias be treated. If the error is a double hypertropia, a central partial tenotomy of each superior rectus should be done. The effect should be equally divided between the muscles, so as to lower the eyes the same number of degrees. If the condition is an uncomplicated double catatropia, a central partial tenotomy of both inferior recti should be done; but care should be taken not to do too much, for the reason that a slight double catatropia is much to be preferred to a very slight double hypertropia.

A double hypertropia complicated by plus cyclotropia is caused by the inferior obliques. If these two errors are very high in degree, and especially if there is want of converging power, the conditions would be better corrected by cutting both inferior obliques near their origin. These operations would correct not only the double hypertropia and the plus cyclotropia, but would also give an increase of converging power. If these combined errors are not so high in degree, or if high in degree and there is little or much esotropia, a division of the inner and central fibers of both superior recti would be indicated; for these operations would correct the double hypertropia and the plus cyclotropia and at the same time would lessen convergence.

A double hypertropia complicated by a minus cyclotropia is caused

by the two superior recti, and the operation to be done is a marginal tenotomy of both these muscles, dividing the temporal and central fibers. In such a case there is practically always some esotropia also, which will be slightly increased by these operations; but the latter can be treated as set forth under the head "Esotropia."

A double catatropia complicated by a plus cyclotropia is caused by the inferior recti alone, and should be relieved by a division of the temporal and central fibers of both these muscles. If in such a case there is want of converging power, this would be helped by these operations; but if there is an excess of convergence, this will be made greater. How to deal further with such a case has been set forth already.

The most common form of vertical heterotropia is hypertropia of one eye and catatropia of the other. If there is no complicating cyclotropia, the first operation should be a central partial tenotomy of the superior rectus of the hypertropic eye, the aim being to accomplish more than half the correction, rather than less; and the second operation, after from two to four weeks, should be a central partial tenotomy of the inferior rectus of the catatropic eye, with the view of placing the visual axes in the same plane. These operations will result only in lessening the tonicity of the muscles that are too strong. If some of the old errors should remain, the third operation should be a straight-forward shortening of the inferior rectus of the hypertropic eye. These three operations should correct the most aggravated vertical error; but a fourth operation could be done—viz., a straight-forward shortening of the superior rectus of the catatropic eye.

Hypertropia of one eye and catatropia of the other, complicated by a plus cyclotropia, should be corrected by a marginal partial tenotomy, including the nasal and central fibers, of the superior rectus of the hypertropic eye; and a marginal partial tenotomy, including the temporal and central fibers, of the inferior rectus of the catatropic eye.

Hypertropia of one eye and catatropia of the other, complicated by parallel cyclotropia—plus in one eye and minus in the other—would require one method of procedure if the hypertropic eye had the plus cyclotropia, and a very different method if the hypertropic eye had the minus cyclotropia. In the former case the marginal tenotomy of the superior rectus of the hypertropic eye should include the nasal and central fibers, and the marginal tenotomy of the inferior rectus of the catatropic eye should include its nasal and central fibers; while in the latter case the tenotomy would include the temporal and

central fibers of the superior rectus of the hypertropic eye and the temporal and central fibers of the inferior rectus of the catatropic eye.

CYCLOTROPIA.

This may be (1) compensating, (2) comitant or (3) paralytic. In the first there is binocular single vision; in the second there is neither binocular single vision, nor is there diplopia; in the third there is diplopia. In (2) the absence of diplopia is due to mental suppression of the images in one eye.

Compensating cyclotropia is divisible into two classes. (1) That caused by uncorrected oblique astigmatism, or by misplaced correcting cylinders. For a full consideration of this kind of compensating cyclotropia the reader is referred to the section on **Oblique astigmatism.** (2) The other kind of compensating cyclotropia has for its cause malposition of the eyes, one eye being lower than its fellow. The plane of the primary isogonal circle should be at right angles to the median plane of the head, which is possible only when the two eyes are level. In such eyes the vertical axes are parallel with the median plane of the head. The line connecting the centers of the two eyes must lie in the plane of the primary isogonal circle and it must be common to the planes of all the secondary isogonal circles. When one eye is lower than the other, the plane of the primary isogonal circle must be inclined, therefore not at right angles to the median plane of the head. The horizontal retinal meridians, except in uncorrected oblique astigmatism, must lie in the plane of the primary isogonal circle, therefore they must be made to incline towards the side of the lower eye, which inclination must be accomplished by the superior oblique of the higher eye and the inferior oblique of the lower eye, in response to a stimulus sent from either the eighth or the ninth conjugate center, as it may be the right or the left eye which is higher. This is parallel cyclotropia, while the other form of compensating is non-parallel. The latter is effected either by the sixth or the seventh conjugate centers or by the two (right and left) sixth basal or fusion centers, or by the two (right and left) seventh basal or fusion centers.

The cure of non-parallel compensating cyclotropia is the correction of the astigmatism. There can be no cure for the compensating parallel cyclotropia, except the loss of one eye. In monocular vision of unlevel eyes, the vertical axis of the uncovered eye would become parallel with the median plane of the head. If unlevel eyes are astigmatic and each eye is tested while the other is under cover, the axis of each cylinder must be shifted from the position thus found, in the direction of the lower eye, so that in binocular vision the axes of the cylinders

may be in the planes of the inclined best corneal meridians. The correcting cylinders of such astigmatics cannot bring complete relief from eye-strain—no relief at all to the muscles forced to produce the parallel cyclotropia.

Comitant cyclotropia. This, like comitant esotropia already studied is binocular and is always non-parallel. It may be plus or minus, and practically always exists as a complication of some one or two other forms of heterotropia. It should always be considered when any case of heterotropia is to be treated. As in other kinds of heterotropia, comitant cyclotropia is binocular, but shows itself only in the unused eye. The varieties of cyclotropia are plus and minus.

In plus cyclotropia the error is caused by both inferior obliques or by both inferior recti. If the inferior obliques cause the error, the necessary complication will be double hypertropia; and if the inferior recti are the cause, the necessary complication will be double catatropia. The error would be shown in only one eye at a time. The interni, with their attachments too low, can help the inferior recti in the development of plus cyclotropia; and the externi, with their attachments too high, can aid the inferior obliques in the causation of the plus cyclotropia.

Minus cyclotropia can be caused by the superior obliques alone, when the complication will be double catatropia; it can also be caused by the superior recti, when the complication will be double hypertropia. Externi that are too low can help the superior obliques in the production of minus cyclotropia, and interni that are too high can aid the superior recti in the production of minus cyclotropia.

Plus cyclotropia of one eye, with hypertropia, is caused by the inferior oblique; plus cyclotropia of the other eye, with catatropia, is caused by the inferior rectus.

Cyclotropia, of whatever kind, can be detected and measured by means of the cyclophorometer, used as in the investigation of cyclophoria. Because of the amblyopia that usually exists in one eye, the red glass should be placed in the cell behind the rod that is before the better eye. The prism of five degrees should be placed in the cell behind the rod that is in front of the amblyopic eye, base either up or down—in the former position if this eye is hypertropic; in the latter position if it is catatropic. If the red streak of light is below, and the two streaks converge at the ends corresponding to the red glass, there is plus cyclotropia; if they converge at the other ends, there is minus cyclotropia. Turning the rods in the directions that will parallel the streaks, and at the same time make them appear to be horizontal, measures the error; and the pointing of the index also names the error.

If the two stand in the lower nasal quadrant, the error is plus; if they stand in the lower temporal quadrant, the error is minus.

Cyclotropia, like the other forms of heterotropia, is alternating—that is, the fixing eye, whichever it may be, will have its vertical axis parallel with the median plane of the head, while the vertical axis of the other eye will be torted out or in, as the case may determine. It is also comitant, the angle being the same in all positions of the eyes.

Cyclotropia, caused by paralysis, or paresis, is non-comitant, and will be attended by most annoying symptoms. The symptoms of comitant cyclotropia are those common to the other forms of comitant heterotropia, including the loss of vision in one eye, caused by mental suppression. Reflex symptoms are caused by nervous tension of the weaker oblique of the fixing eye, that the vertical axis may be made parallel with the median plane of the head.

Treatment of cyclotropia. When cyclotropia is a complication of esotropia, exotropia, hypertropia, and catatropia, it should be treated as has been set forth. Here it is necessary to speak of the treatment of cyclotropia when it is the chief error; it rarely exists alone. If there is much plus cyclotropia, complicated by double hypertropia, but no marked lateral error exists, the operative effect should be equally divided between the two eyes. Either the two inferior obliques should be divided completely (for the reason that a partial division of these muscles near their origin seems impossible) with the Graefe knife; or a marginal tenotomy of both superior recti should be done, consisting of a division of the nasal and central fibers of each, leaving uncut the temporal fibers. The results of the operation on the superior recti would be the same in kind, if not in degree, as those done on the inferior obliques—namely, the two eyes would be partly, if not wholly, relieved of the outward torsion, and they would be relieved more or less of the double hypertropia. In the absence of any lateral deviation, the only remaining muscles to be subjected to operations are the inferior recti, whose nasal fibers should be shortened or advanced equally. The operations on the inferior recti would correct more or less of the plus cyclotropia, and the double hypertropia.

Plus cyclotropia complicated by hypertropia of the right eye and catatropia of the left eye, should be treated first by one or the other of two operations on the right eye—that is, either the inferior oblique should be cut, or a marginal partial tenotomy, including the nasal and central fibers, should be done on the superior rectus. Either of these operations would correct wholly or in part both the plus cyclotropia and the hypertropia of this eye. The next step would be to divide the temporal and central fibers of the inferior rectus of the left eye,

which would correct wholly or in part both the plus cyclotropia and the catatropia of this eye. If, after these operations have been done, there should remain some of both the plus cyclotropia and the hypertropia of the right eye and catatropia of the left eye, one other operation should be done on each eye—namely, the nasal margin of the right inferior rectus and the temporal margin of the left superior rectus should be either shortened or advanced.

Plus cyclotropia uncomplicated by any other deviation, should be relieved by either a nasal marginal tenotomy of both superior recti or by a nasal marginal advancement or shortening of both inferior recti; or, in cases demanding it, both operations should be done on each eye. Since a double catatropia would result, necessarily, from either marginal tenotomies of the superior recti or marginal shortenings or advancements of the inferior recti, the former operation should be preferred, for the reason that it is both more easily done and less annoying, afterwards, to the patient. In those cases in which subduction is greater than normal (more than three degrees), after the nasal marginal tenotomies of the superior recti have failed to correct the plus cyclotropia, temporal marginal tenotomies of the inferior recti should take the place of the nasal marginal shortenings or advancements.

Minus cyclotropia complicated or uncomplicated is so rare that its treatment may be dismissed with the statement that the part of a superior or inferior rectus that should be cut for plus cyclotropia should be advanced or shortened for a minus cyclotropia, and the part of these muscles that should be advanced or shortened for a plus cyclotropia should be cut for a minus cyclotropia. The same holds true also as to operations that might be indicated on the lateral recti, when errors of these muscles complicate minus cyclotropia. The superior oblique has probably never been divided, nor should this be done, for a minus cyclotropia.

In the discussion of the treatment of the various forms of heterotropia, much has been taught that cannot be appreciated by the reader who is not well grounded in the principles set forth in the earlier part of this section. In this department of ophthalmology theory directs practice and practice sustains theory. Every operation on the extrinsic ocular muscles should be done with the view of enabling the superior and inferior recti to plane the visual axes, the interni and externi to so control these axes in this plane as to make them intersect at the point of view, and the obliques to parallel the vertical axes of the eyes with the median plane of the head, or what is the same thing, must keep the horizontal retinal meridians in the plane of the primary

isogonal circle. In accomplishing these aims operations should be so done as not to reduce below the normal the duction and version power of a single muscle.

PARALYSIS AND PARESIS OF THE OCULAR MUSCLES.

A brief review of the nerve supply is essential to a clear understanding of paralysis or paresis affecting one or more of the ocular muscles. This can be done by a study of Fig. 8 and plates i to vi, found in an earlier part of this section.

Causes. Paralytic or paretic heterotropia may be caused by disease or injury of the muscle, or muscles, affected; by disease or injury involving the nerve trunk; by disease of the nucleus at the base of the brain; by disease in the internal capsule or corona radiata; and by disease or injury of a conjugate brain-center in the cortex.

Occasionally children are born with paralysis of one or more ocular muscles.

The disease that most often causes paralysis or paresis of the ocular muscles is syphilis. The muscles most frequently involved, when syphilis is the cause, are those supplied by the third nerve; but the superior oblique and the external rectus may suffer from the same cause. The history of the case will show whether syphilis is the probable cause. Ocular paralysis is one of the remote results of syphilitic infection.

Rheumatism affecting the muscle itself, or involving the nerve in its course, is not infrequently the cause of ocular paralysis or paresis. The external rectus is the muscle that most frequently suffers from this cause.

A cold contracted from undue exposure to dampness, to a draught, or any other causative agent, may cause, in some inexplicable way, paresis or even paralysis of any one of the ocular muscles.

Tumor, or other disease of the internal capsule and the corona radiata, will cause paralysis of conjugate movements, but not paralysis of the muscles; duction power, which is reflex in character, will not be involved, but the verting power, which is volitional, will be impaired or lost. In such cases, symptoms referable to other parts are always associated with the eye symptoms.

Injury or disease of the cortex, involving any one of the nine conjugate centers, will result in paralysis or paresis of one muscle connected with each eye; but the paralysis will show itself in the absence of verting power, with no loss of duction power. To illustrate: If the third conjugate center alone is involved, there can be no convergence, but because of freedom from disease of the fourth and fifth conjugate centers the two eyes can be made to turn harmoniously to

the right or to the left; and adduction, which is reflex, will be unimpaired.

Disease or injury of the orbit involving the parts around the sphenoidal fissure, disease in the orbital cavity behind the eye, and disease or injury of the muscles themselves, can cause paralysis of any one or several of the orbital muscles.

Individual forms of paralysis. (1) The third nerve.—If the cause is in the basal nucleus or in the course of the nerve before it divides into its several branches, the following conditions will be present: (a) ptosis; (b) the eye will be turned out more or less by the unopposed externus, and it cannot be rotated in; (c) the eye will be turned slightly down and will be torted in by the unopposed superior oblique; the eye cannot be turned upward, for both elevators—the superior rectus and the inferior oblique—are involved, and it can be turned downward only slightly by the superior oblique, for the chief depressor—the inferior rectus—is powerless; (d) the pupil will be dilated and the accommodation will be suspended. There will be neither headache, nausea, nor dizziness; for the fallen lid cuts off the light from the eye, and the brain-centers—the fusional centers—are not excited.

If the disease involves only one branch after it leaves the main nerve, only one muscle will be affected. If the diseased branch is the one supplying the muscle that elevates the upper lid, the only symptom will be ptosis. If the involved branch is the one supplying the internus, both adduction and adversion will be impaired or abolished, the eye being turned out; and because of the absence of ptosis there will be crossed diplopia, associated with headache, nausea, and dizziness, due to excitation of brain-centers. If the affected branch is the one supplying the inferior rectus, sub-duction will be impaired or absent, and sub-version by the superior oblique will be only slight; and, for the same reason given above, there will be diplopia in the lower field, headache, nausea, and dizziness. If the involved branch is the one supplying the superior rectus, super-duction will be impaired or lost, and super-version by the inferior oblique will be only slight, and there would be diplopia in the upper field, headache, nausea, and dizziness. If the branch affected is the one supplying the inferior oblique, super-duction (by the superior rectus) will probably be unimpaired, and super-version will be only slightly lessened, and there will be diplopia in the upper field, headache, nausea, and dizziness on attempting to look up, as would be true, also, when the superior rectus is paretic. The symptoms caused by paresis of the inferior rectus (and by paresis of the superior oblique, as will be shown later) are

always more pronounced, for the reason that we look down more than we look up. If the branch implicated is the one going to the ciliary ganglion, thence to the ciliary muscle and the sphincter of the iris, there will be complete loss of accommodation and full dilatation of the pupil; but if the ciliary ganglion itself is the involved part, there will be complete loss of accommodation, but the pupil will not be fully dilated. Both the sphincter of the iris and the dilator fibers will be paralyzed, hence partial dilatation, but complete inactivity of the pupil. The symptoms will be: Dread of light, inability to see near objects well, and pain referable to the eye.

(2) The fourth nerve. Since this nerve supplies only the superior oblique, the symptoms are the same, whether the disease is at the basal nucleus of origin, or in the course of the nerve. The eye is torted out by the unopposed inferior oblique; sub-version is limited, but subduction is probably not much impaired. There is always diplopia in the lower field. Nausea, vomiting, dizziness, and headache are nearly always pronounced.

(3) The sixth nerve. Since this nerve supplies only the external rectus, the symptoms are always the same, whether it is diseased at its basal nucleus or in its course. The eye will be turned in, and both abduction and abversion will be abolished. There will be homonymous diplopia. There being no ptosis to cut off light from the affected eye, the cortical centers will become excited, and there will be headache, nausea, and dizziness when attempting to look toward the corresponding side.

It is only when there is extensive disease at the base of the brain, or disease involving all the structures in the sphenoidal fissure, or extensive disease in the orbit itself, that paralysis of all the muscles of one eye is possible. The symptoms of such a condition would be immobility of the eye in any direction; protrusion of the eye, even when the disease causing it is not in the orbit, for there would be relaxation of all the external muscles; diplopia would be pronounced in all directions (unless the optic nerve has been involved in the disease process within the cranium), were it not for the fact that the upper lid usually falls far enough down to cover the pupil; the ptosis would be complete, were it not modified by the protrusion of the globe; and, finally, the accommodation would be suspended and the pupil dilated. An ophthalmoplegia externa, without associated paralysis of the ciliary muscle and sphincter of the iris, is inconceivable, and that, too, whether the disease causing it is intracranial or intraorbital. On the contrary, paralysis of the muscles within the eye may be unassociated with paralysis of the external muscles.

Diagnosis. There can never be any doubt as to what rectus muscle is involved when the paralysis is complete; but when there is paresis, it is often a difficult matter to determine to which eye the affected muscle belongs and what muscle is involved, for in some of these cases there is no perceptible squint, and apparently no limitation of movement. The unfailing test for paresis and (were it necessary) for paralysis is the diplopia test. This test will always be responded to in the direction of action of the affected muscle, and it invariably determines the eye to which the affected muscle belongs, and unerringly points to the paretic muscle. For the laterally acting muscles the following rule may be formulated: *The candle will appear single in the left field, if the affected muscle is a right vertor, but will be doubled in the right field, and vice versa, if the affected muscle is a left vertor; and the eye to which the affected muscle belongs will see the candle that is farthest removed (the false candle), and the affected muscle is on that side of this eye corresponding to the direction of doubling.* If the doubling is to the right, the paretic muscle is a right vertor, and is, therefore, either the right externus or the left internus. If the right eye sees the candle farthest removed, it is the right externus; but if the left eye sees the false light, it is the left internus. Nothing could be more easily accomplished than the complete diagnosis of paresis of a right vertor or a left vertor.

Although there are two sub-vertors and two super-vertors for each eye, the determination of the question, "To which eye belongs the paretic muscle?" is as easy as can be; and the difficulty in the way of finding the involved muscle is only apparent. If the affected muscle is a sub-vertor, the candle will appear single above, but double below, the horizontal plane, and vice versa, if the affected muscle is a super-vertor.

The following is the rule for finding the eye to which the affected muscle belongs and for locating the paretic muscle: The eye to which the paretic sub-vertor or super-vertor belongs sees the candle that is farthest removed (either above or below) from the horizontal plane, and the direction of the leaning of the false candle determines whether it is a straight or an oblique muscle that is involved. If the doubling is below the horizontal plane and the false candle leans toward the same side, the inferior rectus is the paretic muscle; if it leans toward the opposite side, the superior oblique is the paretic muscle; but if the doubling is above the horizontal plane and the false candle leans toward the corresponding side, the inferior oblique is paretic; if it leans toward the opposite side, the superior rectus is paretic.

The accompanying cuts illustrate perfectly the rules given above.

In the cuts illustrating paresis and paralysis of the right and left vertors, the doubling is represented as existing when the vertical plane has been reached, the distance between the false and the true candles increasing as the candle is carried farther in the direction of action of the affected muscle. This is always true in paralysis, but in paresis the doubling may not occur, in passing from the field of fusion into the field of diplopia, until the vertical plane has been passed. Likewise, in the cuts representing paralysis and paresis of the sub-vertors and

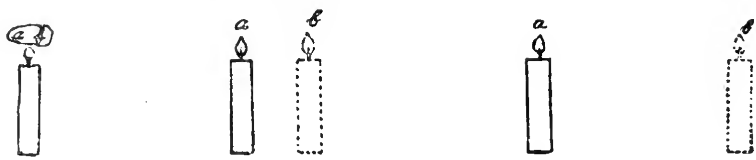


Fig. 43.

super-vertors, the doubling is represented as having occurred before reaching the horizontal plane, in passing from the fusion field into the field of diplopia.

Fig. 43 illustrates paralysis and paresis of a right vertor, either the right externus or the left internus. If the right eye sees candle b, the affected muscle is the right externus; but if the left eye sees candle b, the affected muscle is the left internus. A red glass before either eye shows quickly which eye it is that sees the false candle; covering either eye with a card will also show which eye it is that sees candle b.

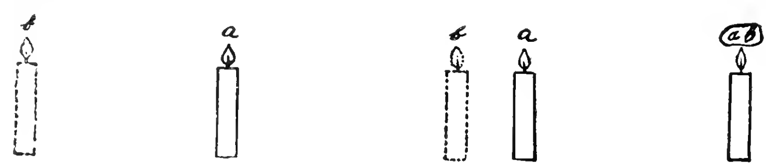


Fig. 44.

The false candle may be above or below the true, or of the same height as shown in the cut, depending on the state of imbalance, or balance, of the vertically acting muscles. A leaning of the false candle will appear whenever there is a cyclophoria.

Fig. 44 illustrates paralysis or paresis of a left vertor, either the left externus or the right internus. If the left eye sees candle b, the affected muscle is the left externus; but if the right eye sees candle b, it is the right internus.

The false candle in paralysis of a right or a left vertor is not always parallel with the true candle. When this is true, the direct antagonist

of the paralyzed muscle has not an ideal attachment to the globe; its attachment is either too high or too low. When the healthy muscle is an internus, if the false candle leans toward the side of the affected eye, its attachment is too high, or there is minus cyclophoria; but if the false candle leans toward the opposite side, its attachment is too low, or there is a plus cyclophoria. Just the opposite is true when the healthy muscle is an externus.

Fig. 45.

Fig. 46.

The false candle may be higher or lower than, or level with, the true, depending on the state of imbalance, or balance, of the vertically acting muscles.

Fig. 45 and Fig. 46 illustrate paralysis of a sub-vertor muscle of either one eye or the other. Below, in parallel columns, will be shown the significance of each cut. Inclination toward the opposite side points to the superior oblique, while inclination toward the same side points to the inferior rectus:

Fig. 45 is illustrative of paralysis of either the superior oblique or the inferior rectus of the eye that sees candle b. If the right eye sees it, the affected muscle is the inferior rectus; but if the left eye sees it, the affected muscle is the superior oblique.

Fig. 46 is illustrative of paralysis of either the superior oblique or the inferior rectus of the eye that sees candle b. If the right eye sees it, the affected muscle is the superior oblique; but if the left eye sees it, the affected muscle is the inferior rectus.

Fig. 47.

Fig. 48.

In either case the false candle may be to the right or left of the true, depending on the relationship between the lateral recti muscles.

Fig. 47 and Fig. 48 illustrate paralysis of a super-vertor muscle of either one eye or the other. Below, in parallel columns, will be shown the significance of each cut. Inclination toward the opposite side points to the superior rectus, while inclination toward the same side points to the inferior oblique.

Fig. 47 is illustrative of paralysis of either the superior rectus or

the inferior oblique of the eye that sees candle b. If the right eye sees it, the affected muscle is the superior rectus; but if the left eye sees it, the affected muscle is the inferior oblique.

Fig. 48 is illustrative of paralysis of either the superior rectus or the inferior oblique of the eye that sees candle b. If the right eye sees it, the affected muscle is the inferior oblique; but if the left eye sees it, the affected muscle is the superior rectus.

As in paresis or paralysis of the sub-vertors, the false candle may be to the right or left of the true, depending on the relative strength of the laterally acting muscles.

In making a diagnosis of paralysis or paresis of the ocular muscles, by means of the diplopia test, the candle need be carried only in the four cardinal directions—that is, the head should be erect, and, in testing for paresis of the right and left vertors, the candle should be carried only along the extended horizontal plane of the head directly to the right and left of the vertical plane; and in testing for paresis of the sub-vertors and super-vertors, the candle should be carried only in the extended median plane of the head, above and below the horizontal plane.

For detecting paralysis or paresis of the sub-vertors and super-vertors, nothing serves better than a horizontal line at a distance of twenty feet. If the sub-vertors are at fault, elevating the head, while still looking at the line, will cause it to double, the false line appearing below the true. If the false line leans toward the corresponding side, the affected muscle is the inferior rectus; but if it leans toward the opposite side, the affected muscle is the superior oblique.

When a right vertor or a left vertor is paralyzed, the resulting deviation might be mistaken for comitant lateral heterotropia. This may be avoided in two ways—first, by a test of the verting power, when the affected eye will always lag behind its fellow, if the two eyes are turned in the direction of action of the paretic muscle, whereas, in comitant squint, the deviating eye moves always through as great an arc as the fixing eye; secondly, by covering the eyes alternately, the secondary deviation will always be greater than the primary, when there is paralysis. But in comitant squint the secondary and the primary deviations are always the same.

In paralytic squint there is always diplopia in one part of the field, with binocular single vision in the opposite part; while in comitant squint there is no diplopia in any part of the field, because of mental suppression.

A very good diagnostic feature is the pose of the head in cases of paralysis of an orbital muscle. In paralysis of a lateral rectus muscle,

the face is always turned in the direction of action of the affected muscle—that is, if a left vertor is paralyzed, the face will be turned to the left in the interest of binocular single vision, and vice versa, if a right vertor is paralyzed; if a sub-vertor is paralyzed, the face will be depressed; and if a super-vertor is paralyzed the face will be elevated.

In "paralysis of motion, rather than of muscle," duction power, which is reflex in the sense that it is not volitional, is not involved. This statement covers all the conjugate brain-centers from the first to the fifth, inclusive—those centers that are concerned with the recti muscles. Since there is no voluntary action of the obliques, the cortical centers governing them must act independently of the will. These centers are the sixth, seventh, eighth, and ninth. That these conjugate centers for the obliques may be involved in pathologic changes must be conceded. Since the object of the sixth and seventh centers is to prevent diplopia, on looking down and up, respectively, these correspond perfectly in action with the reflex centers of the recti that are also concerned with the prevention of diplopia when images are displaced by prisms; therefore they ought not to be affected in disease of the cortex. The eighth and ninth centers are not concerned with the prevention of diplopia; but, what is probably of as much importance, they are concerned with the steadying of all objects in the field of vision whenever the eyes are voluntarily moved in an oblique direction. For instance, when the gaze is directed up and to the right, or down and to the left, the eyes would be torted to the right were it not for the eighth conjugate center, when all objects would be made to appear to incline to the left from their real position, their inclination corresponding precisely with the degree of torsioning. This is prevented by the eighth conjugate center, which maintains the parallelism between the vertical axes of the eyes and the median plane of the head in such a voluntary rotation. It appears, therefore, that disease of this center would be attended by a wheel-like movement of objects whenever the visual axes are made to move up and to the right, or down and to the left, which appearance would not be if the gaze were directed up and to the left, or down and to the right. But if the ninth conjugate center were involved in pathologic change, the wheel-like movement of objects would be observed only when the gaze is up and to the left, or down and to the right. In neither case would there be diplopia.

Should the sixth conjugate center be involved, on looking down at a candle it would appear double, the one seen by the right eye leaning to the left and the one seen by the left eye leaning to the right; the

diplopia would be attended by dizziness and nausea. In the upper field. there would be no diplopia.

Should the seventh conjugate center become diseased, the diplopia would be in the upper field, and the candle seen by the right eye would lean to the right, and the one seen by the left eye would incline to the left. It appears that each oblique muscle is connected by individual nerve fibers with three centers—one center, basal; the two others, cortical. The former center has connected with it fibers from only one muscle, but each of the latter has connected with it fibers from two oblique muscles, one of these belonging to one eye and the other to the other eye and, therefore, they are conjugate centers. All the fibers from these three centers come together and form the trunk of the nerve, a disease of which suspends the independent and conjugate action of the muscle supplied by it; and the muscles of the fellow eye are not involved. The right superior oblique is connected with the sixth conjugate center, as is also the left superior oblique; the right superior oblique is also connected with the eighth conjugate center, as is also the left inferior oblique. Disease of the sixth center, as already shown, gives trouble only when looking directly down; disease of the eighth center causes trouble, as shown above, only when looking up and to the right, or down and to the left. Disease of these two conjugate centers would have no influence over the basal center that gives duction or fusion power to either of the two muscles mentioned—that power that is exercised when images are displaced by oblique astigmatism, natural or artificial.

Each internus muscle is also connected with three centers—one center, basal; the two others, cortical. The former is reflex; the latter, volitional. To illustrate: The right internus has its reflex center—the center giving it duction or fusion power—in the nucleus of the mortor oculi; it is also connected with the third conjugate brain-center, as is also the left internus; it is also connected with the fifth conjugate center, as is also the left externus. All the fibers from these three centers for the right internus form the bundle that constitutes the branch of the third nerve, supplying it with its threefold power. Disease of this branch suspends both the reflex (fusion) and voluntary power of this muscle; it can neither adduct, converge, nor advert the eye to which it belongs. Disease of the third conjugate center involves only those fibers that convey to the muscle the convergence impulse; disease of the fifth conjugate center involves only those fibers that convey the left version impulse; likewise disease of the reflex nucleolus involves only those fibers that convey the fusion impulse. Disease of the third conjugate center would suspend, of course, the converg-

ing power of the left internus also; while disease of the fifth conjugate center would affect the abverting power of the left externus as well as the adverting power of the right internus. Thus each muscle, with its several centers, might be studied.

It only remains to speak of the symptoms that would present themselves, should any one of the five conjugate centers, controlling the recti, become diseased:

(1) Disease of the first conjugate center: inability to supervert the eyes, but no diplopia.

(2) Disease of the second conjugate center: inability to subvert the eyes, but no diplopia.

(3) Disease of the third conjugate center: inability to converge the eyes, with diplopia in the near.

(4) Disease of the fourth conjugate center: inability to rotate the eyes to the right, either cardinally or obliquely, but no diplopia.

(5) Disease of the fifth conjugate center: inability to rotate the eyes to the left, either cardinally or obliquely, but no diplopia.

Treatment. In any form of paralysis of muscle—that is, when the disease causing it is below the internal capsule—the diplopia should be prevented by covering the affected eye, which will relieve all nervous symptoms, such as headache, dizziness, and nausea. The affected eye should be kept under cover until the disease has been cured. In paralysis of the third nerve, nature supplies the cover in the production of ptosis, and usually the last muscle, supplied by the third nerve, to regain its power is the elevator of the upper lid. If any case is clearly rheumatic, it should be treated with large doses of the salicylate of sodium or other anti-rheumatic remedy; if the cause is syphilis, iodide of potassium in increasingly large doses should be given after meals; if the cause is not known, the case should be treated with the iodide of potassium. Early in any case the administration of the fluid extract of jaborandi, in doses of ten to twenty drops at 9 A. M., 3 P. M., and 9 P. M., by promoting the absorption of effused serum, will greatly aid the iodides in the work of hastening the absorption of plastic effusion. Bichloride of mercury in small doses may also be given.

The above remedies should be continued until the diplopia has entirely disappeared. This much having been accomplished, the sulphate of strychnia in doses of $\frac{1}{100}$ to $\frac{1}{50}$ of a grain should be given before each meal. At this stage the interrupted current of electricity, used once daily for ten minutes, will do good. While there is still

diplopia, the strychnia and electricity would do harm, rather than good.

In old cases of ocular paralysis, where there can be no longer any hope of restoration of power to the paralyzed muscle, surgery will do good, in that it will lessen the field of diplopia and give to the patient a more natural pose of the head. The operation should be either an extensive shortening or an advancement of the paralyzed muscle, and never even a partial tenotomy of the antagonist. The muscle plane should be changed or not, when making the shortening or advancement, as may be indicated by the existence or non-existence of torsion.

LAGOPHTHALMOS.

The condition termed ''lagophthalmos'' was so named because it gave to the human eye the appearance of the eye of the hare—always open, asleep or awake. The cause of the condition is disease of the seventh nerve in its course; or at its basal or cortical centers, or between these two—in the internal capsule or in the corona striata. In either case there is a greater or less loss of power on the part of the corresponding orbicularis, and usually all the muscles of the one side of the face are also involved. The location of the disease or injury determines the array of symptoms to be presented in any case.

When the part involved is the basal center of the nerve, or the body of the nerve as it finds its way out to be finally distributed to all the muscles of the face, including the orbicularis of the corresponding side, all these muscles will be paralyzed, and the lagophthalmos will be only one of the symptoms. The skin of the forehead on the affected side is smooth, as if ''ironed out,'' and the patient is wholly unable to throw it into wrinkles, for the reason that this half of the anterior part of the occipito-frontalis is supplied by the diseased nerve; the corrugator supercilii must also be inactive, therefore the brow on that side cannot be drawn down; the various muscles connected with the nose and mouth, action of which goes so far to give agreeableness of expression to the face, cannot receive a nerve impulse, therefore they must be inactive, and the face, on that side, becomes expressionless; the buccinator, which is also supplied by the seventh nerve, loses its power and thus the mastication of food on that side becomes inconvenient—almost impossible—for the reason that, when the tongue presses the food between the teeth, the buccinator being unable to make counter-pressure, the food cannot be kept between the grinders. Soon the patient learns to do all his chewing on the unaffected side. The mouth is always drawn toward the unaffected side, and a laugh will be confined wholly to this side. The patient drinks with difficulty

and cannot whistle. All of these symptoms will be associated with the inability to close the eye.

Both parts—the voluntary and the involuntary—of the orbicularis being involved, the eye will be wide open, and there will be no power to close it. Any great effort to close it will only cause the eye to move upward, as if to hide behind the upraised lid. The lower lid will not be held in contact with the globe, hence the punctum will be displaced. The absence of the batting power makes it impossible for the punctum of the upper lid to carry off the tears; hence there must be an excess of tears in the conjunctival sac. The unprotected eye becomes irritable, as shown by conjunctival redness, excessive secretion of tears, and some dread of light. If the eye is exposed too long and too severely, the cornea may ulcerate, when the eye, of course, becomes painful.

By far the most common cause of lagophthalmos, associated with the other symptoms already described, is inflammation of the middle ear, and the reason is not hard to find. The seventh nerve, as it passes through the aqueduct of Fallopius, in the inner bony wall of the drum cavity, should be completely covered in by bone structure. That this bone covering is complete, in many cases, is made evident by the fact that otitis media is not attended by involvement of the seventh nerve; that it is incomplete, in some cases, is made equally evident because of the fact that in these cases even a very slight otitis media is attended by paralysis of all the muscles of the face. Whenever there is a break in the bony covering, the mucous membrane lining the inner wall of the drum cavity must lie directly in contact with the sheath of the seventh nerve, hence the readiness with which an inflammation of this membrane may involve the nerve. Catarrhal, as well as suppurative, inflammation of the middle ear, in such cases, almost always causes facial paralysis. When such is the cause of facial paralysis, the usual symptoms of inflammation of the ear are present—namely: pain, fullness, and deafness, with some fever. The objective symptoms are also present. If the inflammation causing the paralysis is between the basal center of the seventh nerve and the point where the eighth nerve parts company with the facial nerve, to find its terminals in the internal ear, the resulting pressure will cause deafness, as well as paralysis of the facial muscles; but other symptoms and signs of otitis media will be absent. In the latter case the paralysis of the orbicularis will be as complete as in the former. If the inflammation or injury of the facial nerve is at some point between where it leaves the aqueduct of Fallopius and the point where it divides into its several branches, the facial paralysis will be complete; but

the hearing will not be involved, nor will there be any other symptoms referable to the ear. In all of these conditions the batting power is lost.

When the cause of the lagophthalmos is in the cortex, the lids are not so widely separated, and their batting power, though modified, is not lost. The other muscles of the face may not be involved. If the disease in the cortex, in the internal capsule, or in the corona radiata is extensive, other symptoms will be found in association with the lagophthalmos. Such cases are not so likely to recover full voluntary power over the orbicularis.

Treatment. Whatever may be the cause, the eye should be protected by a flap until such time as the lids may have recovered their power; otherwise the cornea may ulcerate. If otitis is the cause, this condition should be so treated as to prevent suppuration, if possible; but if suppuration occurs, the disease should be so treated as to bring it, as speedily as possible, under control. In all cases the iodide of potassium and the bichloride of mercury should be administered for promoting absorption of inflammatory deposits within the sheath of the nerve. In this work these drugs can be greatly aided by the fluid extract of jaborandi, in ten to twenty-drop doses, three times a day for the first two weeks. Strychnia should be given only when a return of voluntary power to the facial muscles shows that the pressure of inflammatory deposits has been relieved more or less completely. When the cause of lagophthalmos is above the basal, or reflex, center, absorbent treatment is indicated; but, as already stated, recovery is both slow and doubtful.—(G. C. S.)

OPERATIONS ON THE OCULAR MUSCLES.

Operations to influence the position and movements of the eyeball are done on the tendons of the six muscles which have their origins in the orbital walls and their insertions in the sclera. These extrinsic muscles of the eye are arranged in pairs. For certain positions of the eye, and for certain movements, the two muscles of each pair are antagonists. For other positions of the eye and other movements they act together. Their general relations to the eyeball and surrounding parts are shown in the color plate and in Fig. 1.

The recti muscles arise from practically a common origin, around the optic foramen at the apex of the orbit, pass directly to about the equator of the eyeball, and curve around in contact with the sclera to be inserted in its anterior hemisphere. The obliques act from near the anterior margin of the orbit, passing outwards and backwards to the eyeball and curving around it to be inserted in the posterior one-

third of the sclera. The four recti, acting together, tend to draw the eye back into the orbit—to retract it. The two obliques, acting together, tend rather to draw the eyeball forward—to cause it to protrude. All six muscles, acting from the nasal side of the orbit,

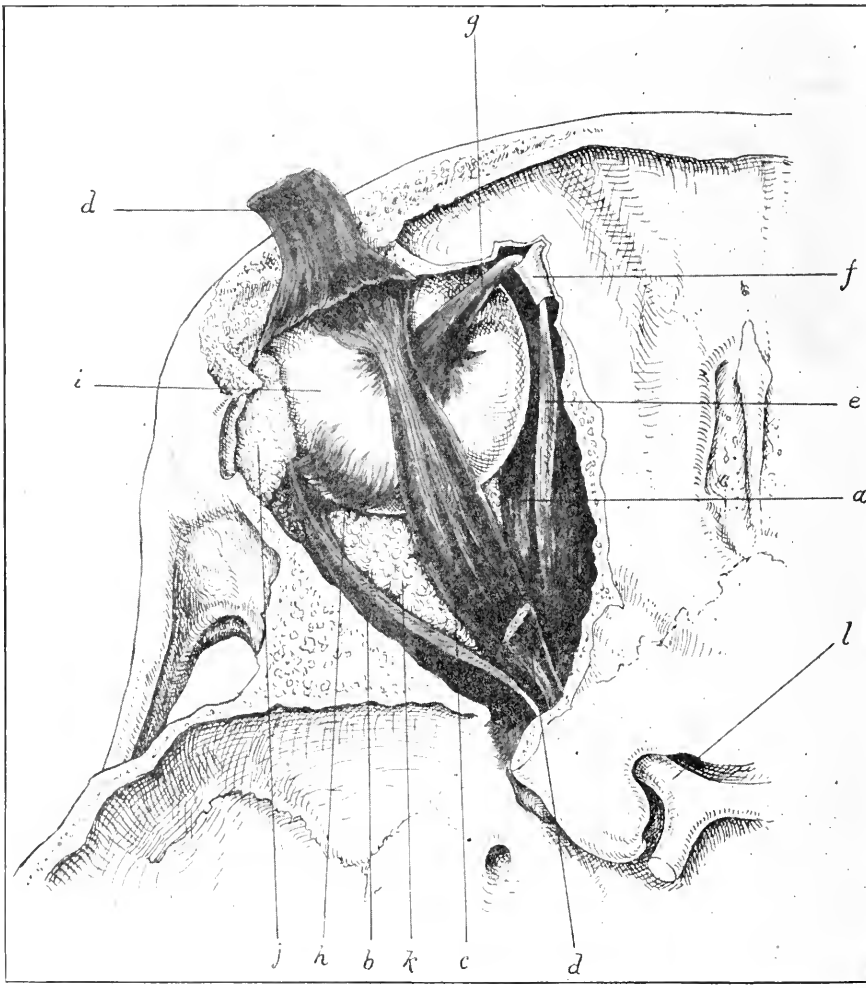


Fig. 1.

Muscles of Orbit as Viewed from Above and Behind.

a. Internal rectus muscle.
b. External rectus muscle.
c. Superior rectus muscle.
d. Elevator of the upper lid (severed).
e. Superior oblique muscle.
f. Pulley of superior oblique.
g. Superior oblique tendon.
h. Inferior oblique muscle (insertion).
i. Eyeball.
j. Lachrymal gland.
k. Orbital fat.
l. Optic nerve.

would, if unopposed, draw the eyeball against the lateral plate of the ethmoid. Each rectus being inserted upon the eyeball in front of its center of rotation, tends to turn the *anterior pole* of the eye towards its insertion. Each oblique, inserted behind the center of rotation, tends to turn the *posterior pole* of the eye towards its insertion; and the anterior pole or cornea, in the opposite direction.

Each of these muscles has a *wide tendon of insertion,* as compared with the length of the muscle. The greatest diameter of the insertion of the biceps is about 1/18 of the total length of the muscle and its tendon, and only $\frac{1}{4}$ or $\frac{1}{3}$ of the maximum diameter of the belly of the muscle. But the breadth of the insertion of the internal rectus is $\frac{1}{4}$ of the length of the muscle, and 1.3 times the maximum diameter of the muscular belly. The insertion of the inferior oblique is about 10 mm. wide, one-half the total length of this muscle and its tendon. Although for certain purposes it is convenient to think of one of the ocular muscles as inserted at a certain point, and acting as a whole upon that point of the sclera, it must not be forgotten that different portions of the muscle are inserted at widely different points, and capable of producing correspondingly different movements of the eyeball.

The rotation produced by a certain force acting tangent to the eyeball depends on the location of the point to which it is applied. Traction towards the apex of the orbit, if applied at the top of the eyeball, above the center of rotation, will tend to turn the cornea up; but applied below the center of rotation will tend to turn the cornea down. All the fibres of the internal rectus muscle, being inserted to the nasal side of the cornea, tend by their contraction, to turn the eye inward. But the upper fibres, inserted higher than the center of rotation, tend to turn the cornea upward; while the lower fibres, inserted lower than the center of rotation, tend to turn the cornea downward. Such antagonistic actions of the extreme fibres of the same muscle probably have an important influence in securing steadiness of the delicate ocular movements. This influence is the greater because of still broader connections of these tendons with the capsule of Tenon. These important relations must be borne in mind when making an operative mutilation of the parts.

Even more important are the *different actions in different positions of the eyeball.* The contraction of the same muscle fibres may produce totally different effects, when the eyeball has been placed in different positions. Take, for instance, the central fibres of the internal rectus muscle. When the line of sight is about level, and the horizontal plane passing through these fibres, passes through the

center of rotation of the eye, their contraction tends to turn the eye in, but neither up nor down. But if the eye be turned upward, say 40 degrees, the relation of the plane of muscular action to the center of rotation is changed, as indicated in Fig. 2, these fibres no longer tend simply to turn the eye in, they also tend to turn it up. But if

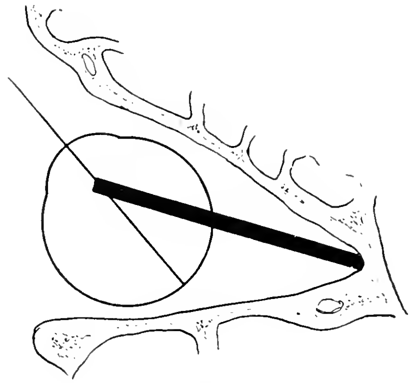


Fig. 2.

Diagram Showing Influence of Internal Rectus Muscle on Vertical Movements; when the eye is turned up helping to turn it up.

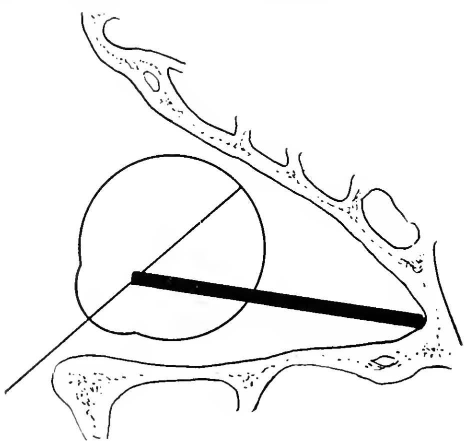


Fig. 3.

Action of Internal Rectus Muscle; when the Eye is Turned Down Helping to turn it down.

the eye is turned downward 40 degrees the contraction of these same fibres will tend to turn it farther down, as shown in Fig. 3.

In all positions of the eye contraction of the internal rectus muscle tends to turn the eye in. This may be called its *primary function.* In certain positions the same contractions assist in turning the eye

up or down; these may be called *secondary functions* or actions of the muscle. Each of the six muscles under consideration has primary and secondary actions. The secondary actions of the external rectus are practically the same as those of the internal rectus and can be understood from the same diagrams.

The superior and inferior recti muscles arising about the optic foramen pass forward and outward, their general direction making an angle of about 26 degrees with the visual axis and median plane of the head, as shown in Fig. 4. With the eyes in the primary position the superior rectus not only tends to turn the cornea up, but also in. The superior and inferior recti acting together become important adductors. Their adductive influence increases as the eyes converge.

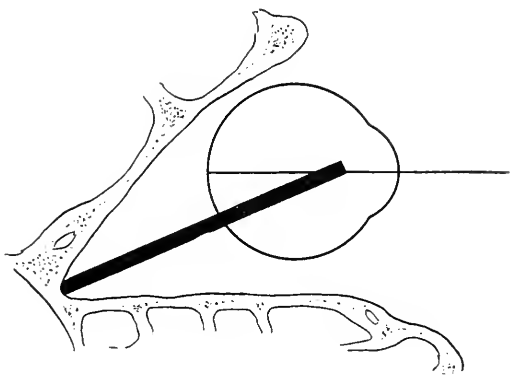


Fig. 4.

Diagram Showing the Angle which the Direction of the Central Fibres of the superior rectus or the inferior rectus makes with the median plane of the head, or with the direction of the visual axis when the eyes are in the primary position.

With the eyeball turned to the temporal side, so that the visual line makes an angle of 26 degrees with the median plane of the head, the central fibres of the superior rectus tend simply to roll the eyeball up; and the contraction of the central fibres of the inferior rectus simply tends to turn the cornea down. See Fig. 5. If the eye be turned still farther toward the temporal side, these central fibres of the superior and inferior recti muscles begin to assist in turning it out. This abductive effect increases the more the eye is turned out, reaching a maximum in cases of extreme divergent strabismus. See Fig. 6. However, for the superior and inferior recti the adductive influence is generally much more important than the abductive; they may be termed *secondary adductors* of the eyeball. Their effect reaches a maximum when the eye is turned strongly in, as it is in high degrees of convergent squint. See Fig. 7.

The superior and inferior recti, aiding the internal rectus, would overpower the external rectus, were it not assisted by secondary abductors—the superior and inferior obliques. The superior oblique passing backward and outward from its pulley to the posterior half

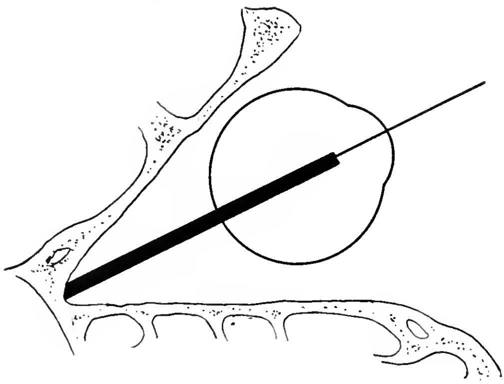


Fig. 5.

Eye Turned 26 Degrees Toward the Temporal Side. The Superior or Inferior rectus tends to turn the eye directly upward or downward.

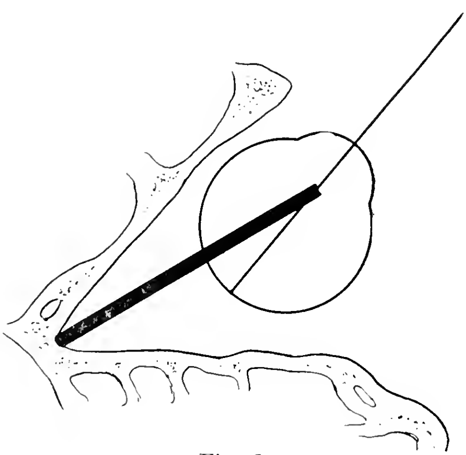


Fig. 6.

Eye Turned More than 26 Degrees Toward the Temporal Side. The Superior or inferior rectus tends to turn the eye out.

of the sclera makes an angle of about 40 degrees with the median plane of the head. The inferior oblique, arising from the wall of the orbit just within the lower nasal margin, passes outward and backward at about the same angle. Acting upon the eyeball back of the center of rotation, together the obliques tend to turn the posterior

pole in, and the cornea out. Their function as secondary abductors of the eyeball is an extremely important one. Their abductive effect is at a maximum when the axis around which they tend to rotate the eye is perpendicular to the direction of their action; that is, when the eye is turned out about 50 degrees. From this position either way

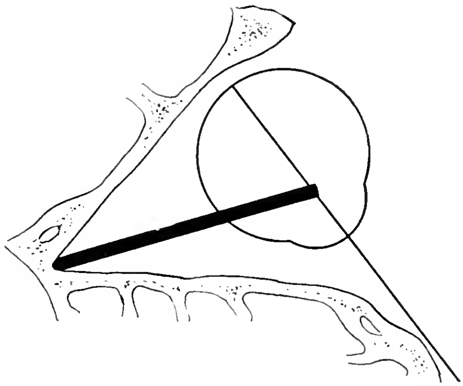


Fig. 7.

Eye Turned Strongly in. The Superior and Inferior Recti Muscles Act as adductors.

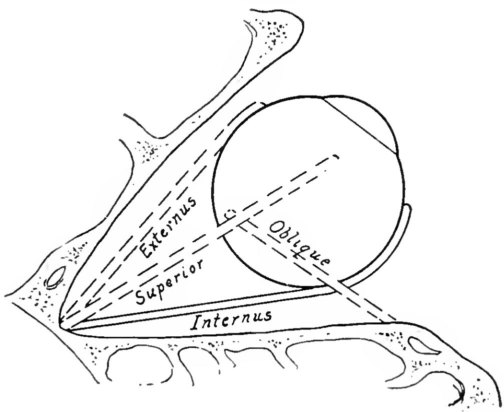


Fig. 8.

Diagram Showing the Actions of the Different Extrinsic Ocular Muscles when the eye is turned strongly outward. The internus alone acts as an adductor. All the others act as adductors.

their abductive effect diminishes. If the eye were turned in, to the direction in which the obliques act, so that the visual axis made an angle of 40 degrees with the median plane of the head, the obliques would cease to act as abductors; and if the eye were turned a little farther in they would begin to act as adductors.

We may take the primary function of the obliques as *torsion* of the eye, or rotation about the visual axes. Contraction of the superior oblique producing *intorsion;* contraction of the inferior oblique producing *extorsion.* A secondary action of the superior oblique is to turn the cornea down. The maximum effect of this kind is produced when the eye is turned in; and no such effect results from its contraction when the eye is turned out 50 degrees. Contraction of the inferior oblique tends to turn the cornea up when the eye is turned in, but this secondary function is lost when the eye is turned out 50 degrees.

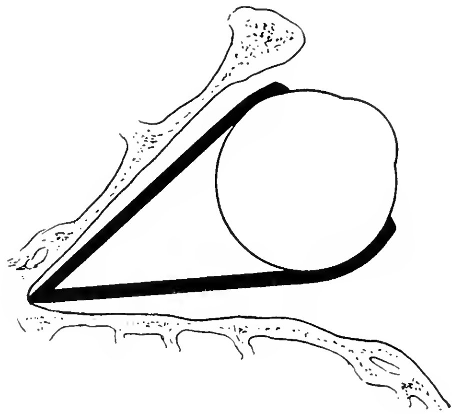


Fig. 9.
Diagram Showing Contact Arcs of the External and Internal Recti Muscles when the eye is turned outward.

In operating upon one or more of the eye muscles, we should carefully consider the effects likely to be produced upon their secondary actions as well as the change aimed at in the primary function.

The maximum effect of a muscular contraction upon the direction of the eyeball is produced when the force is exerted in a direction tangent to the surface of the globe. To secure this maximum effect the tendon of insertion of each muscle curves around the eyeball in contact with the sclera for some distance before being inserted into the sclera. These *contact arcs* permit considerable movement of the eyes, without sacrificing the advantage of having the muscular force exerted tangent to the surface of the eyeball. Figs. 9 and 10 illustrate the contact arcs of the internal and external recti muscles in different positions of the eye. If the eye be turned directly forward the contact arc of the internal rectus is about 5 mm. (about 25 degrees). If

turned out (Fig. 9) it is greater. In the primary position the contact arc of the external rectus is 13 mm. (about 65 degrees). If the eye is made to turn in more than 25 degrees the contact arc of the internal rectus is unwound from the eyeball so that the muscle no longer acts in a direction tangent to the surface of the globe. On the other hand the eye can turn out to the maximum extent 55 degrees, and still retain a contact arc of 2 mm., corresponding to additional rotation of 10 degrees. If the insertion of a tendon is permitted to slip back by tenotomy, the contact arc is to that extent shortened. On the other hand bringing forward the insertion of a tendon will

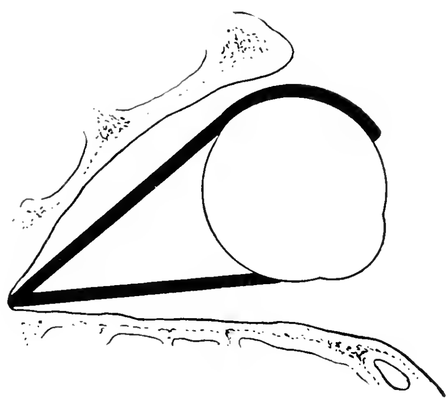


Fig. 10.
Contact Arcs of the External and Internal Recti Muscles when the Eye is turned in.

lengthen the contact arc. The binding down of the tendon to the sclera by cicatricial tissue, where this follows either tenotomy, advancement, or traumatism, diminishes to that extent the contact arc. It shortens the portion of the tendon that can be unwound from the eyeball, giving the effect of a backward displacement of the insertion.

Dimensions of the muscles. Taking as the apex of the orbit the temporal edge of the optic foramen, the center of the eyeball on the average is situated 36 mm. anterior to this. This is about 4 mm. in front of a line joining the outer angles of the two orbits. The center of the ball is about 30 mm. from the median plane of the head, or 16 mm. external to the nasal wall of the orbit. The extreme length of each of the recti muscles with its tendon is about 40 to 45 mm. The width of their insertions and the distance of the center of each insertion from the margin of the cornea, according to Howe (*The Muscles*

of the Eye, Vol. I, p. 34) and the length of the tendon of insertion, according to Fuchs (*Archiv für Ophthal.*, XXX, Pt. 1), are as follows:

	Int. Rectus.	Inf. Rectus.	Ex. Rectus.	Sup. Rectus.
Width of insertion..........	10.3 mm.	9.9 mm.	9.2 mm.	10.6 mm.
Distance from cornea.......	5.7	6.7	7.4	7.6
Length of tendon...........	8.8	5.5	8.7	5.8

These insertions are usually convex toward the cornea, so that the end of each insertion, the insertion of the edge of the muscle, is dis-

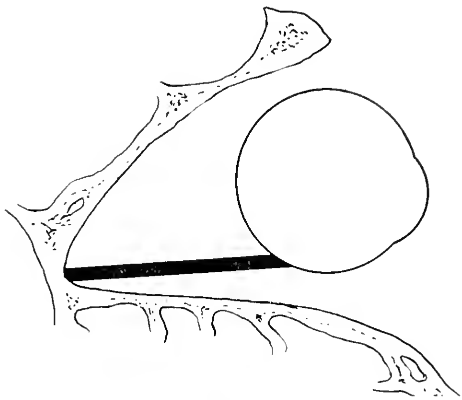


Fig. 11.
Diagram Showing Loss of Contact Arc from Tenotomy.

tinctly farther back from the cornea than the figures given. There are considerable variations in individual cases so that the position of the insertion may vary from 5 mm. or even less, for the internus, to 12 mm. back from the cornea for the temporal margin of the superior rectus. The insertion may also depart from a straight or regularly curved line, some portions of it being irregularly thrown forward or behind other parts.

In normal eyes the insertions of the lateral recti may often be recognized through the conjunctiva and subconjunctival tissues. For the superior and inferior recti this is not often possible. But after a tenotomy the sclera, exposed by slipping back of the tendon, is commonly noticeable on close examination. The insertion of these tendons may present further anomalies. Slips are sometimes given off from the edges of the tendons to be attached beyond the usual lateral limits of the insertion; or from the surface of the tendon in contact with the

eyeball, to be inserted into the sclera farther back than the main insertion. In all cases connective tissue extends from the muscle sheaths and tendons, to fuse with other connective tissue structures of the orbit, especially with the so-called capsule of Tenon. These additional connections vary widely and in some cases may be of practical importance.

The superior oblique muscle, passing from its origin forward along the inner wall of the orbit, has a length of about 40 mm. before it reaches the pulley. From the pulley to its insertion on the eyeball its length is from 15 to 20 mm. At the pulley the tendon is not more than 3 or 4 mm. in diameter. But it spreads out into a fan-shaped

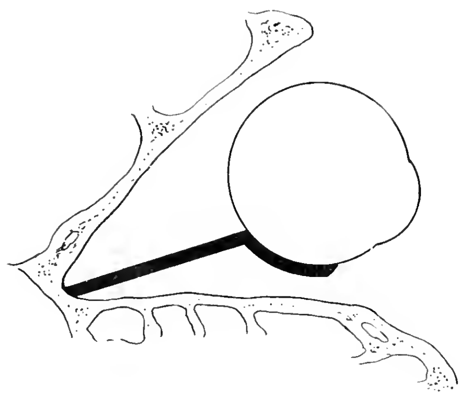


Fig. 12.
Practical Loss of Contact Arc by Adhesion of Tendon to Sclera Back from the normal insertion.

membrane; so that its insertion, chiefly in the upper posterior temporal quadrant of the globe is, in some cases, more than 15 mm. across; although sometimes its breadth has been set down as 7 mm. or less.

The inferior oblique arises from a depression in the orbital plate of the superior maxilla; just within the lower margin of the orbit, and to the temporal side of the nasal bone. At its origin the muscle is most accessible for operative interference. Passing back and to the temporal side, just beneath the inferior rectus, it is inserted in the outer, posterior, lower quadrant of the sclera. The breadth of the tendon at the line of insertion varies from 7 to 12 mm. The lines of insertion of both obliques vary markedly in form and position, and their tendons fuse with the adjoining connective tissue structures even more completely than do those of the recti. On these accounts, as well as because of their deep situation, operative interference near their insertions into the sclera is not practicable.

Of the other muscles of the orbit the elevator of the upper lid is fully considered under ptosis. The involuntary muscles are also concerned with the retraction of the lids, and are not subjected to operation. The anomalous slip, known as the transversalis, comes off from the elevator, and is to be considered with that muscle. The tensor tarsi, Horner's muscle, is thought by Howe to be concerned in the sinking

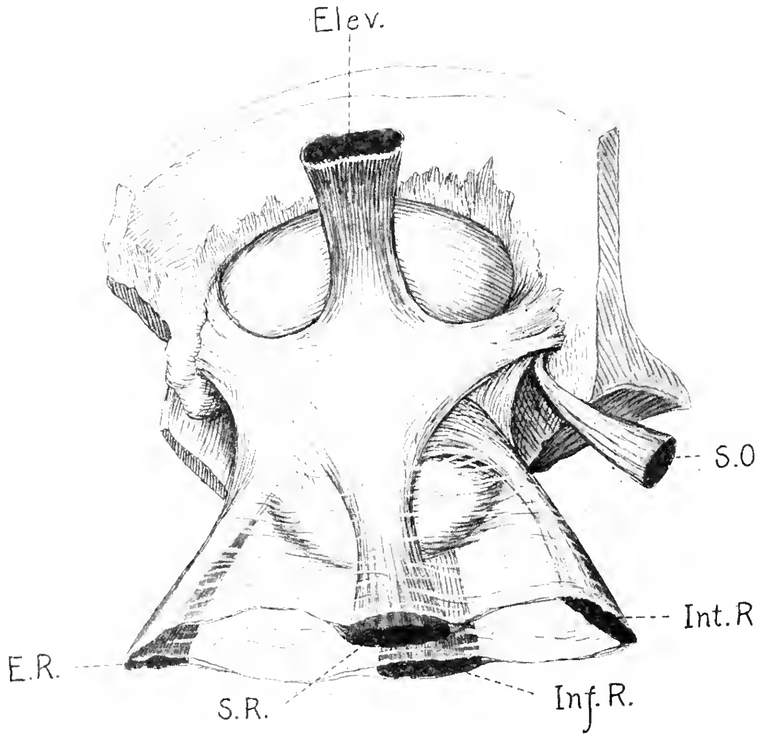


Fig. 13.

Relations of the Extrinsic Ocular Muscles to the Connective Tissue Structures of the orbit as viewed from above and behind (after Motais). Note the lateral expansion of the tendons and the delicate membranous connections of the muscle sheaths. Elev. Elevator of upper lid. E. R. External rectus. S. R. Superior rectus. Inf. R. Inferior rectus. Int. R. Internal rectus. S. O. Superior oblique.

of the caruncle that follows some tenotomies. It arises from the lachrymal bone behind the lachrymal sac; and passes outward dividing into two parts, one of which lies behind each canaliculus to be inserted into the tissue of the two lids. It is commonly classed with the lid muscles, and supposed to influence the removal of the tears.

Connective tissue structures. The orbit is occupied by connective tissue, in which the orbital fat, the muscles, eyeball, ocular vessels

and nerves are embedded. This connective tissue is in some parts extremely loose and non-resistant. Other parts are condensed into membranes and ligaments calculated to resist considerable force. These membranes and ligaments are conveniently mentioned and described under special names. But we should bear in mind that they are continuous with the looser, unspecialized, orbital connective tissue.

The more important membranous condensations of the orbital connective tissue constitute the so-called *capsule of Tenon*. Its general arrangement within the orbit is shown in the color plate.

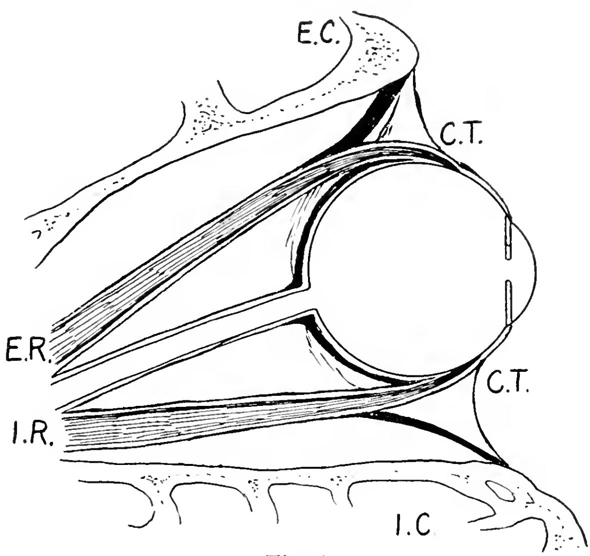


Fig. 14.

Condensations of Orbital Connective Tissue Shown in Black. Diagram of Horizontal section. E. C. External check ligament. C. T. Capsule of Tenon where it is most disturbed in muscle operations. I. C. Internal check ligament. E. R. Externus rectus muscle. I. R. Internal rectus muscle.

The membranes which stretch from the margins of each of the recti muscles become especially thickened anteriorly, and spreading out from the muscle sheath and tendon constitute the "little wings" or "fins" ("ailerons") of Motais (*Anatomie de l'Appareil Moteur de l'Oeil de l'Homme et des Vertébrés*, p. 86) which are generally called the *check ligaments*. Still farther forward the connective tissue condensation forms a membrane enclosing the posterior portion of the globe and reflected to extend to the margins of the orbit, the *orbito-ocular fascia*. This is the part of the capsule of Tenon to be dealt with in ocular muscle operations. This portion is shown in Fig. 14, representing a vertical antero-posterior section of the orbit.

The membrane covering the eyeball at the insertion of the muscles is comparatively thin and little noticeable. But it is sufficient to offer a serious obstacle to the introduction of the strabismus hook, if this is attempted without on opening having been made in it. The deeper thickenings which stretch from behind the eyeball to the mar-

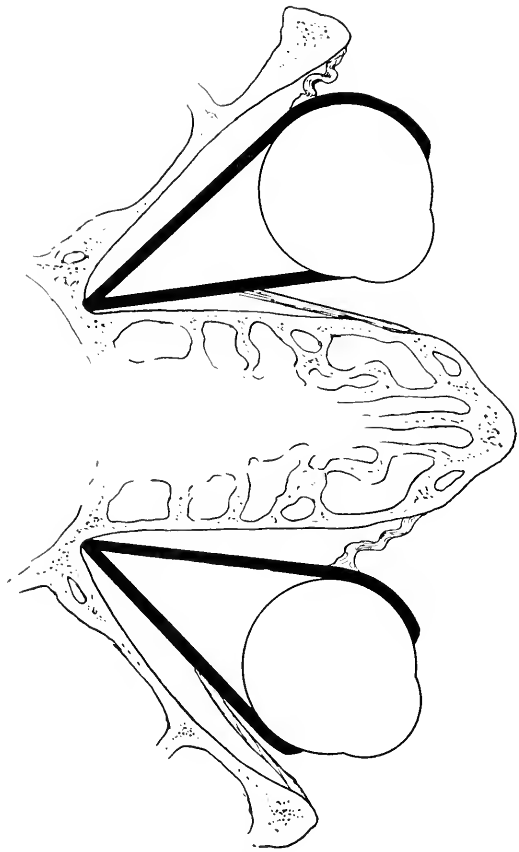


Fig. 15.

Diagram Showing Tension and Relaxation of the Lateral Check Ligaments, when the eyes are turned strongly to the right. The ligaments connected with the right externus and left internus are tense. Those connected with the right internus and left externus are relaxed.

gin of the orbit furnish a very important support which holds the eyeball in proper position against the conjoined actions of the ocular muscles. It constitutes a sort of hammock, in which the ocular globe is turned and swung, by the straight and oblique muscles. Damage to this supporting structure is chiefly responsible for the displace-

ments of the eye that have followed reckless operating for strabismus. While the ocular muscles have their main insertions into the sclera and act chiefly upon it, they have minor attachments to the structures surrounding the eyeball, so that each movement of the ocular globe is normally accompanied by a certain amount of movement in surrounding parts.

The curtain of condensed connective tissue that stretches from the eyeball to the margins of the orbit, part of the so-called capsule of Tenon, is thickened opposite the recti muscles. Although these thickenings are not sharply limited and vary considerably in extent, thickness, tension, and relations with the neighboring structures, it is con-

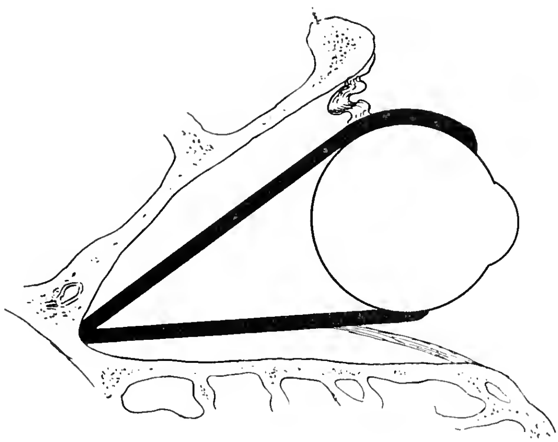


Fig. 16.

Diagram Showing Influence of Tenotomy and Advancement on the Check Ligaments. The internus having been tenotomized its check ligament is put upon the stretch. The externus having been advanced its ligament is relaxed.

venient to recognize them under the name of *check ligaments*. As described by Motais, they arise from the orbital surface of each muscle, passing forward to be inserted in the orbital margin. Their relations are also illustrated in Fig. 15.

The check ligament constitutes a sort of supplementary tendon of insertion for the muscle, which, however, is so relaxed under ordinary conditions that none of the muscular force is exerted through it. If, however, the muscle is very strongly contracted, as the external muscle of the right eye is represented to be in Fig. 15, the check ligament may be put upon the stretch so that the muscle can no longer exert much force to rotate the eyeball, the movement of which is thus limited by the ligament. Backward displacement of the muscle insertion, as by tenotomy, tends to put the check ligament on the stretch,

and thus the movement of the eyeball in that particular direction is still more limited. Such a condition following tenotomy of the internal rectus is indicated in Fig. 16. On the other hand the advancement, shortening or tucking of a tendon tends to bring forward the muscular origin of its check ligament, relaxing it more than the normal, and removing its power to check the rotation of the globe.

The *arteries and venous branches*, which supply the parts involved in these operations, are not sufficiently constant to need discussion in this connection. The larger veins are always visible. They occasion the most troublesome bleeding. Often the necessary incisions, especially that in the conjunctiva, may be so placed as to avoid them. Or the necessary division of a large vein may be deferred until it will cause the least annoyance and delay. The motor nerves of the ocular muscles enter the muscles so far back as to be outside the field of operation. The sensory nerves are branches of the first division of the fifth cranial nerve. In a general way they pass from the nasal toward the temporal side of the orbit.

History. Strabismus, either as a temporary condition associated with convulsive seizures, or permanent in certain individuals, has been recognized from the earliest period of medical history. But not even the anatomy of the muscles concerned in ocular movements was understood with approximate accuracy until studied by Fallopius in the 16th century. After this the absence of perceptible pathologic changes in the muscles, even with strabismus of long standing, and the temporary character of some squints that were not differentiated from the permanent deviations, tended to discourage attempts to relieve the deformity by operative procedure.

In the middle of the 18th century, "Chevalier" John Taylor claimed to straighten cross-eyes by operation. This educated and skillful charlatan has received much notice in literature. (See the admirable paper and bibliography by Coats, *Royal London Ophthalmic Hospital Reports,* v. 20, p. 1.) He never mastered an operation for this purpose; and during his later career he seems to have restricted his claims to other operative cures that he felt more sure of accomplishing. He left no impression upon the general practice of his contemporaries and successors with regard to strabismus, except the mere suggestion that squint might be curable by operation.

Sir Charles Bell, in 1823, divided the recti and oblique muscles of the eyes of lower animals; and concluded that the former had to do with the voluntary, and the latter with the involuntary movements of the eyes. In 1827 Anthony White suggested that by cutting the ocular muscles we could correct strabismus. But the suggestion was

not acted on, and, clinically, squint received little attention. In the text-books the account of it was very brief. It occupied one and one-half pages in Littell's *Manual* of 250 pages, and in the four volumes of von Ammon's *Zeitschrift für Ophthalmologie,* which appeared from 1830 to 1837 inclusive, strabismus is merely mentioned two or three times as a symptom.

In 1838 Stromeyer (*Beiträge zur Operativen Orthopedie.* Hannover, 1838) thus described an operation which he called "myotomy for strabismus," having performed it on the cadaver: "The good eye should be closed and the patient directed to turn the affected eye away from its false position. For internal squint a fine hook may then be thrust into the ocular conjunctiva at its inner margin; and confided to an intelligent assistant, who will keep the eye turned out. The conjunctiva being raised with forceps, should be divided by means of a cataract knife, making an incision near the inner canthus. The traction on the tissues is to be increased until the internal rectus appears, under which a fine probe may be passed. It is to be divided with curved scissors, or with the knife used in opening the conjunctiva."

Pauli (Schmidt's *Jahrbücher*, Bd. 24, p. 347) did the operation easily on the cadaver; but, attempting it on a patient, failed to fix securely the eyeball and divide the tendon. Guérin demonstrated Stromeyer's operation on the dead body, and claimed to have preceded Dieffenbach in applying it to the living patient (Cunier, *Annales d'Oculistique,* T. 3, Liv. 5 and 6). But the era of operation upon the eye muscles may be said to begin with the announcement of Dieffenbach (*Medicinische Zeitsch.*, Nov. 13, 1839) that he had obtained a perfect result in a case of convergent strabismus by division of the internal rectus muscle.

The operation was done on the 29th of October, 1839, and is thus described by Howe (*Muscles of the Eye.* Vol. II, p. 293): "The head of the patient, a boy of 7, being fixed against the chest of one assistant, and the lids held apart by two hooks in the hands of a second assistant, thereupon I pushed a third hook through the conjunctiva at the inner angle of the eye and quite through the deep cellular tissue there, and that hook I gave to a third assistant. Then I stuck a fine little double hook into the sclerotic at the inner angle of the eye, and holding it in the left hand, drew the globe as far outward as possible. I incised the conjunctiva, close to the globe where it is spread out at the inner angle of the eye. Going deeper, I dissected the cellular tissue from the ball, and then divided the muscle, with a pair of fine eye scissors, close to the globe."

This report, widely published, attracted the attention of surgeons who engaged in the operative treatment of strabismus in all parts of the world. Established authorities like Velpeau and Mackenzie published supplements to their text-books, describing this new triumph of surgery. Monographs and journal articles appeared in all civilized countries; the number of such writings published in 1840 to 1845, inclusive, being greater than in the thirty years that followed.

In this epidemic of squint operations, by design or by accident, substantially every form of myotomy or tenotomy that has yet been devised was put into practice. It is frequently stated that in these early operations it was customary to divide the belly of the muscle. This is erroneous. It was common in those days in writing about the operation to make no distinction between the tendon and the belly of the muscle, and the division of the tendon was as likely to be called a "myotomy" as a "tenotomy." Thus Mackenzie (*Diseases of the Eye.* 4th Edition, p. 361) heads his account of the operation "cure of strabismus by myotomy," although he does not mention any cutting of the muscle, but writes specifically of cutting the tendon. Later he speaks of "myotomy" or "tenotomy as it has been called." Some of the plates representing the operation give the impression that the muscular belly was to be cut, when the accompanying description shows that it was not. Thus Baumgarten (*Das Schielen und dessen Operative Behandlung.* Leipzig, 1841, 8vo, p. 88) always speaks of myotomy, and his plate represents his strabismus hook under the belly of the muscle, two-thirds of an inch or more back from the margin of the cornea. Yet he describes his operation as cutting the tendon three lines from its insertion. Dieffenbach (*Schielen und die Heilung,* 1842. Berlin) and others did come to advocate cutting the belly of the muscle, to secure a greater effect in strabismus of high degree. But this was urged as an improvement or modification of the usual operation. In Dieffenbach's monograph, and again in his general treatise (*Die operative Chirurgie.* Leipzig, 1848, Bd. 2, p. 166) he describes the section as made in the tendon, three or four lines from its insertion, or for low grades of strabismus, directly at the insertion. Post (*Observations on the Cure of Strabismus.* New York, 1841), whose monograph is dated June 5th, 1842, made a vertical incision one-fourth to one-half inch in length, "so as to expose to view the insertion of the internal rectus muscle." He expressly states "the division of the muscle should be as near as possible to its insertion." Although to secure a greater effect "it may perhaps be advantageous to divide the muscle one-sixth of an inch behind the insertion, and then to snip with scissors the portion remaining attached to the

sclerotica." This latter precaution was taken to avoid an "unseemly prominence," often amounting to a sort of fungous growth requiring subsequent snipping away, a complication which gave considerable trouble to the early operators for squint.

Duffin (*Practical Remarks on the New Operations for the Cure of Strabismus or Squinting.* London, 1840, 8vo, p. 147) ascribed some of the bad results of the early operators "to pushing the muscle back into the posterior and lateral part of the orbit with the handle of the scalpel, as has been recommended by some surgeons." His manner of dividing the tendon was "cutting it across with a pair of scissors inserted between the convexity of the hood and the sclerotic coat."

A general review of the causes for the relative discredit into which the operative treatment of strabismus shortly fell is thus given by Wilde (*The Dublin Journal of Medical Sciences,* 1845, Vol. XXVIII, pp. 201, 209): "It is needless to add that many were operated on whose eyes should never have been meddled with. In some it failed for want of knowledge, or dexterity in the operation; a few were reduced to the condition exactly the reverse to what they were before the operation, and fully as bad, namely, that of extreme divergence; in some the eye becoming remarkably staring and prominent, resembling lagophthalmos; others squinted worse than before; several had the caruncle and semilunar fold of the conjunctiva completely cut away so as to leave a deep unseemly gap between the globe and the inner canthus of the eye, as where much violence was used in operating, particularly by those who poked into the orbit with a large dissecting forceps, to look for the muscle, without the aid of a blunt hook. In some the deformity, though relieved at the moment of operation, returned shortly after; and in several cases the squinting, though cured in the eye originally affected, seized upon the other afterwards." Fifteen years later Graefe (*Archiv. für Ophthalmologie,* Bd. III, p. 177) and Critchett (*Lancet,* 1855, Vol. I, p. 507), without suggesting anything radically new, but pointing out the dangers of recklessness and describing minutely a good technique, were able to impress upon the profession the operations which still bear their names.

The dangers of reckless operating should be impressed upon every one who undertakes the treatment of squint. In a recent paper on "Strabismus Produced by Operations for Strabismus," Todd (*Journal of the A. M. A.,* v. 67, p. 264) classifies such cases thus: 1. Cases in which operations have failed fully to correct the strabismus. 2. Cases in which an over-correction has occurred, and strabismus of the opposite kind, though in the same plane, exists. 3. Cases in which

strabismus in a different plane has resulted. 4. Exophthalmos or enophthalmos.

The use of the blunt hook, now called the "strabismus hook," to catch up the tendon, is credited by Duffin to Lucas, who suggested it within the first few months following the introduction of the operation. (*Provincial Medical and Surgical Journal,* October, 1840); also (*Practical Treatise on the Cure of Strabismus.* London, 1840, p. 48.) Subconjunctival tenotomy was early proposed by Guérin (*Gazette Med. de Paris,* 1842, X), and its relative merits were canvassed by the writers in those earlier years. The so-called Critchett operation will be described among the operations still in use.

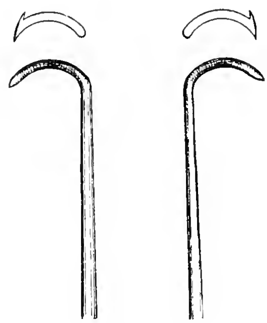


Fig. 17.
Double Curved Barbed Strabismus Hooks. (Bolton.)

Since Critchett published his method the most important modifications of tenotomy have been the method of Snellen; with its modifications, and changes of the size and proportions of the instruments by Stevens; and the systematic extension of the operation to adjoining tendons. These will also be referred to hereafter. Many variations have been practised by individual operators. Bolton (*A Treatise on Strabismus with a Description of New Instruments.* Richmond, Va., 1842, 12mo, 36 pl. with plate) modified the strabismus hook as shown in Fig. 17, by placing a blunt barb on the end, to prevent the tendon from slipping off the hook before it was fully divided. Baumgarten *(loc. cit.)* instead of dividing the tendon with scissors used a sharp knife, claiming that it caused less pain to the patient. Bonnet also raised the tendon and cut it from within outward with the cataract knife. Dieffenbach (*Die Operative Chirurgie.,* Bd. II) and others, like Post, often excised a portion of the tendon. *"Plastic tenotomy"* or division of part of the tendon at one point and the remaining fibres at some other point was proposed by Verhoeff (*Klin. Monatsbl.*

f. Augent., p. 234) in 1903, and (*Tr. Sec. on Ophth. Amer. Med. Assoc.*, 1907, p...) Todd in 1907. To get an effect similar to that of tenotomy, elongation of the recti tendons by oblique division and suture, was proposed in 1902 by Stephenson (*Tr. Ophthal. Soc., United Kingdom,* v. XXII, p. 276); and in 1905 by Landolt (*Arch. d'Ophtal.,* v...., p. ....). Tenotomy of the inferior oblique suggested in 1885 by Landolt (*Arch. d'Ophtalmol.,* Vol. V, p. 402) has been placed upon a scientific basis by the recent papers of Duane and Posey (*Arch. of Ophthalmol.,* Vol. XLV, pp. 33 and 137).

Dieffenbach in his monograph (1842), mentions the use of a suture to diminish the excessive effect of tenotomy, and also the excision of tissue or cauterization at the insertion of the weakened muscle. In 1848 Cunier (*Bull. Acad. Roy. de Med., de Belge,* II, p. 158) suggested the use of the suture to prevent the sinking of the caruncle and apparent protrusion of the eyeball, an unsightly sequel of Dieffenbach's operation. He passed a suture by means of a fine needle through the middle of the lips of the incision held in position by hooks.

The *thread operation* is often credited to Graefe. But it was first suggested by Gulz and used by Dieffenbach in 1841. In 1842 after tenotomy of the external rectus for divergent squint Wilde (*Dublin Journal of Medical Science,* Vol. XXVIII, p. 201) used a ligature passed twice through the stump of the tendon and fastened to the nose by strips of adhesive plaster, taking care not to have the ligature touch the cornea. He first placed a strip of adhesive plaster on the nose, then drew the ligature over it sufficiently taut, placed a second strip over the ligature which was doubled back, and a third strip twice as wide over all. In 1845 he reported 18 cases treated in this way; 14 of convergent and 4 of divergent strabismus. The ligature was left so long as it remained tense. Wilde suggested using the ligature without cutting the tendon.

The first steps in the development of *advancement operations* appear in the case reported by Guérin (Desmarres. *Maladies des Yeux,* p. 803). Tenotomy of both internal recti had been followed by divergence; and tenotomy of the external rectus repeated three times failing to relieve the deformity, Guérin freed the eyeball from the temporal side, dissected up the remains of the attachment of the internal rectus muscle, drew it forward with forceps, and attached it to the sclera. The advancement of Critchett, which will be described later, was first published in 1858, in the account by Bader (*Roy. London Ophth. Hospital Rep.* Vol. I, p. 250) of a case treated at the Royal London Ophthalmic Hospital. The patient suffered from congenital divergent strabismus. Tenotomy of both externi, and turning

the eyes in with a thread failed to correct it. A fortnight later advancement was done on both the interni, giving as the ultimate result a very slight internal strabismus.

In 1871, Weber (*Literature Verzeichniss,* No. 6, p. 415) published an operation for advancement with a single suture which never was much used outside of Germany. But the similar operation, described by de Wecker (*Annales d'Oculistique.* T. 70, p. 225) in 1873, is often regarded as the beginning of modern advancement operations. The history of advancement operations is that of a multiplication of slight modifications in detail, rather than any progressive serial development. The time at which any particular operation was suggested is of interest only as bearing upon personal questions of priority. The more important of these dates are mentioned in connection with the descriptions of the operations.

Tendon transplantations of the eye muscles, or lateral displacement of the tendon insertion to change the function of the muscle, are quite recent. The first account of such an operation for paralysis of the superior oblique was published by the writer in 1903 (*Ophthalmic Review,* v. XXII, p. 61). In 1907 Hummelsheim reported (*Bericht der Ophthalmol. Gesellschaft Heidelberg,* v. ...., p. 248) two cases in which parts of the tendons of the superior and inferior recti were joined to the tendon of a paralyzed external rectus to restore abduction.

Classification of operations. Strabismus operations may be classified thus:

(A) Operations done to diminish the influence of a particular muscle or muscles upon the position and movements of the eyeball, as tenotomy, and operations to increase the effect of tenotomy.

(B) Operations done to increase the influence of a particular muscle or muscles upon the position and movements of the eyeball, as operations for advancement, tendon-tucking.

(C) Operations to modify the influence of a particular muscle or muscles so as to change the direction in which it will tend to turn the eye, or to alter the relative proportions of the influences exerted in producing different movements, as by lateral displacement of the insertions, tendon transplantation.

(D) Miscellaneous operations to influence the position of the eyeball. Combinations of two or more of these operations may be done as a single operation.

It will be convenient first to describe the separate operations; and then to consider in a general way the indications for their performance, and the relative advantages and disadvantages of various procedures that might be used for a certain condition. The designating

of an operation by the name of its designer, while at first convenient, has now become an important source of confusion. The same operator has successively devised operations somewhat similar, yet bearing less resemblance to each other than to operations known by other names. Therefore the different procedures are here designated by characteristic features, rather than by names of operators who may have had some share in devising them.

Condition of patient. Operations for strabismus are not emergency operations, and should be done when the patient is in the best possible condition. In young children the extent of the squint varies largely with the health of the child, and even with fatigue. Accurate, permanent correction can only be attained if the case has been studied with the patient in normal condition. Although the vascular tissues involved have great power of resisting infection, this ought not to be unnecessarily presumed upon. A case of total suppuration of the cornea from streptococcus infection, and subsequent shrinking of the eyeball in a boy of 16, has recently been reported by Wirtz (*Zeitschrift für Augenheilkunde,* January, 1910, p. 55), following tenotomy of the internus with advancement of the externus. Erysipelas (Holmes, G. R. *Am. Jour. Otology, Rhinology, and Laryn*, September, 1907) from permanent streptococcus infection of the nasal sinuses should be borne in mind. Recent influenza is especially to be guarded against, because of its liability to attack the eye, and because the patient may attach little importance to it if the preceding symptoms have been slight. Hemophilia should be inquired for. An operation should not be undertaken in the presence of trachoma, or lachrymal conjunctivitis, or even chronic blepharitis, without first trying to bring the eye into the best possible condition for it.

Position. One may operate with the patient seated or lying down. In either position the back of the head should be fully supported. The illumination should be clear, and may come from a broad source. Corneal reflexes, that may embarrass the operator in doing a cataract extraction or iridectomy, do not interfere with operating on the eye muscles.

Anesthesia and hemostasis. For local anesthesia many operators depend upon a solution of cocain instilled into the conjunctiva for twenty minutes before beginning the operation; or crystals of the cocain salt laid on the conjunctiva over the tendon to be divided. Some use the cocain solution or crystals again after opening the conjunctiva and capsule. Browne (*Brit. Med. Jour.*, 1887, Vol. II, p. 1277) devised a perforated tube, shaped like a strabismus hook, with which he injected a cocain solution beneath the tendon before dividing it.

Woodruff (*Jour. Ophth. and Oto-Laryngol.* April, 1910) raises the conjunctiva with forceps and injects a 1 per cent. cocain solution mixed with one to one thousand of adrenalin beneath the conjunctiva; and massages the resulting swelling for a few minutes. More efficient means are recommended by Bruns (*New Orleans Med. and Surg. Jour.* Dec., 1909) of injecting a solution containing cocain and adrenalin, dissolved in physiologic salt solution, along the course of the muscle to be operated on, five to eight minutes before beginning the operation.

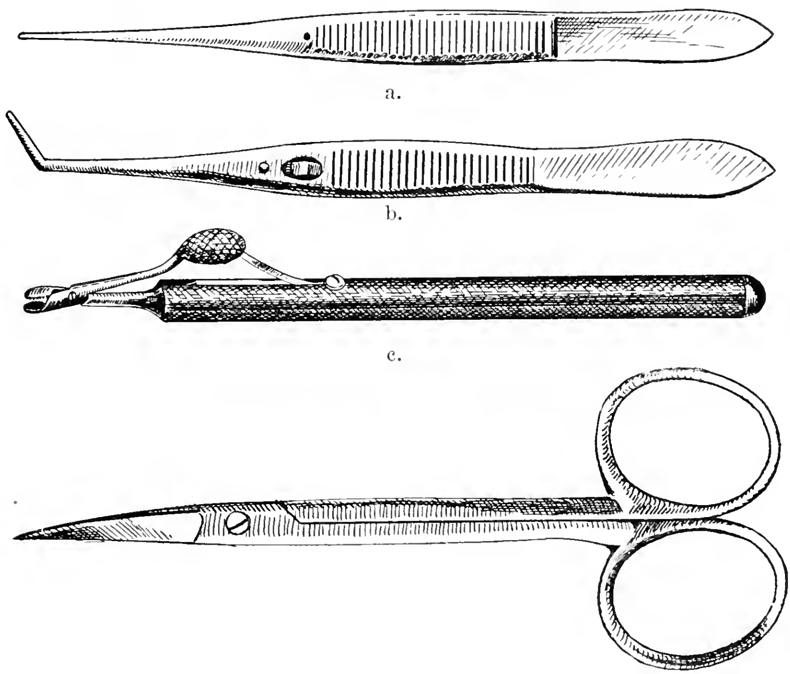
It is a great convenience to have oozing controlled by the application of one of the adrenal preparations. By this resource, and care to avoid cutting the larger visible vessels, troublesome bleeding may be avoided in most cases. A solution of adrenalin of quite moderate strength, 1 to 2,000 or less, is quite sufficient. Two or three drops should be applied about two minutes before beginning the cutting. Local anesthesia is sufficient for any of these operations, when done by one thoroughly familiar with the procedure, upon an adult who possesses good self control. But for young children and nervous, excitable adults, general anesthesia is sometimes necessary for an accurate and satisfactory operation. It is more necessary for advancement operations, with accompanying division of the advanced tendon, than for simple tenotomy, or tendon tucking.

Instruments. These are a stop speculum, lid elevator, various forceps, scissors, strabismus hooks, needles and sutures. The speculum may be any of the standard forms. If the operation is done in a sitting posture a short, light speculum, like that of Mellinger, as adapted by Beard, is to be preferred. If the patient is in the recumbent position a heavier instrument, such as the Moorfields model, may be quite as satisfactory. For these operations it is not of such great importance that the instrument be instantly removable as that it be firm and rigid.

The *forceps* may include the usual broad serrated conjunctival fixation forceps, although these are not necessary. Fine-toothed forceps can be used to seize the conjunctiva, and such are necessary for accurately seizing and lifting the deeper connective tissue structures. For fixing the eyeball during the introduction of a stitch into the sclera, the crossbill, embedding, fixation forceps of Critchett are satisfactory. The points are brought together on the surface of the sclera and then thrust into it as the handles are pressed together. For seizing the tendon advancement forceps, as those of Prince, with a spring or sliding catch are needed. Needle forceps should be adapted to holding small needles, and allowing a ready release. No spring or slide catch is required. The instrument of Stevenson is satisfactory.

The *scissors* should be slightly curved on the flat, about 40 mm.

radius, with fine rounded points. From the joint to the point should be between 20 and 25 mm. The handles may be either of the ordinary form, or the forceps handles suggested by the writer (Jackson, E. *Med. News,* LVI, p. 184) in 1890; and independently by Wescott (*Ophth. Rec.,* 1897, p. 486), who combined them with the narrow rounded points of the Stevens' scissors. The forceps seissors are easier to use in any direction, without the operator having to change his position.



d.

Fig. 18.

Instruments Generally Used in Muscle Operations:

a. Strabismus forceps.
b. Prince advancement forceps.
c. Stevenson needle forceps.
d. Strabismus scissors, ordinary form.

It is essential that the scissors should cut perfectly, as the recti tendons and their finer prolongations readily slip between the blades, if these are not accurately adjusted or not heavy enough to prevent springing.

The *strabismus hook* should be rather delicate, the one most used about ¾ of a mm. thick at the curve, the end slightly bulbous, projecting 7 or 8 mm. from the direction of the shank and slightly bent back, making a curve of more than 90 degrees. Hooks larger, projecting 10 or 11 mm., and smaller, projecting 5 or 6 mm., may also be used. But

the very fine hooks are liable to catch in connective tissue structures where it is desired that they should glide smoothly past. The double, or clamp hook of de Wecker is used by some operators, but many find

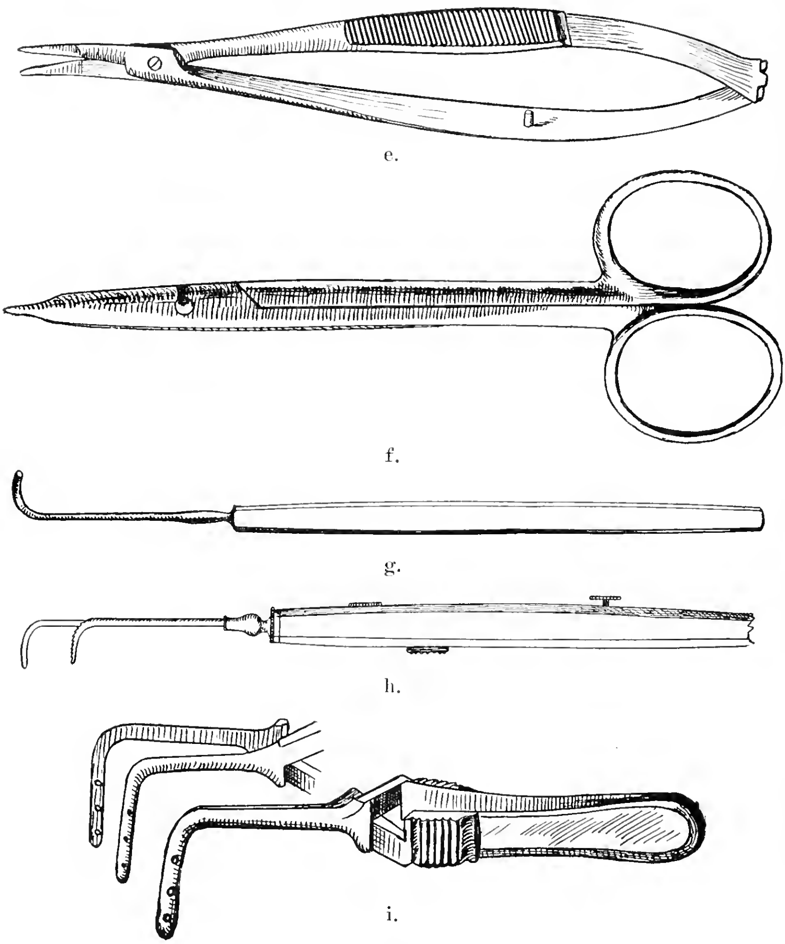


Fig. 19.

Instruments Generally Used in Muscle Operations (Continued).

e. Strabismus scissors with forceps handles.
f. Stevens strabismus scissors.
g. Strabismus hook.
h. de Wecker's double hook clamp.
i. Howe's muscle clamp.

the tendon forceps of Prince a more convenient instrument. An effective forceps hook has also been devised by Deschamps.

The hook of Clark and various tendon tuckers will be described in connection with the operations for tendon tucking.

The *needles* should be curved. The smallest obtainable are to be used for placing stitches in the sclera. A size somewhat larger is better for conjunctival or subconjunctival stitches. The *suture material* is usually silk, as large as can be conveniently threaded in the needle.

A difficulty with sutures employed in these operations is the tendency to cut out prematurely. Catgut may be employed and presents advantages for buried sutures in advancement operations. But it is inferior to silk in that it is less flexible, and more bulky for a given tensile strength. Other instruments employed only in particular forms of operations will be described in connection therewith. The strabismus instruments should be made entirely of metal, and rendered aseptic by brief boiling.

Operations to diminish the influence of a muscle. Tenotomy by the open method. This is the operation which has been most widely practised for strabismus. It was the method of the early operators, and was reformulated by Graefe. The instruments required are the speculum, fine strabismus forceps, strabismus hook, scissors, needles, silk and needle forceps for the conjunctival suture.

The speculum is introduced in the eye to be operated on, and the other eye is closed. For tenotomy of the internal rectus the patient is directed to turn the eyes to the side of the one to be operated on, relaxing the contracted muscle, and rendering retention in proper position easier for the surgeon, and less uncomfortable for the patient.

The operator stands at the head, or either side of the patient; whichever will interfere least with the light, and give the readiest access to the tendon. Usually with the patient recumbent, standing by the right side gives freest access to the right eye, and by the left side for the left eye. Taking the forceps in the left hand and the scissors in the right, the conjunctiva and subconjunctival tissue are seized over the insertion of the tendon, 6 mm. to the nasal side of the corneal margin, in such a way as to raise a horizontal fold of tissue. This fold is cut with the scissors so as to make a vertical conjunctival incision 8 or 10 mm. long, parallel with a tangent at the nasal margin of the cornea. Graefe (*Arch. f. Ophthalmol.*, Vol. III, p. I, p. 177) made the incision nearer the cornea. Any episcleral tissue remaining undivided by the original cut is then picked up with the forceps, and the incision completed down to the sclera. With the point of the closed forceps, or the point of the closed scissors, a little blunt dissecting is done at the lower angle of the wound, downward and backward 3 or 4 mm. to get beneath the lower margin of the tendon.

The scissors are then laid aside, the forceps are used for fixation; and the strabismus hook, held in the right hand, is entered with its tip

in the channel just prepared, passing first downward and backward 3 or 4 mm. The tip being pressed firmly against the sclera is then carried upward about 10 mm., the hook being so held and turned as to follow its tip with the least traction or disturbance of tissue. The bulbous tip is then allowed to leave the sclera, being slightly elevated, and brought forward toward the cornea until arrested by the tendon at its insertion.

The assistant may now sponge the wound, and the surgeon should see that the whole width of the tendon is held upon the hook. It is safest to make the end fairly emerge above the upper margin of the tendon. To accomplish this the subconjunctival wound may be slightly stretched upward with the point of the forceps, and the tissue teased

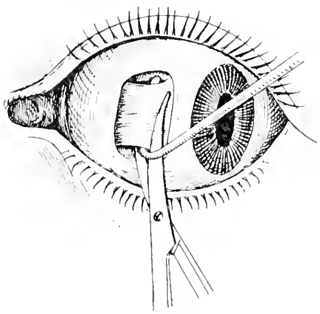


Fig. 21.
Tenotomy by the Open Method. Tendon Held on Strabismus Hook. Scissors introduced.

through to the end of the hook; or the hook may be liberated by snipping the tissue overlying the point with the scissors.

The fixation of the eye may now be accomplished entirely by the hook. This is the time for special stretching of the muscle, to be alluded to later. In any case the tension on the muscle, almost inevitably resisted by the patient, is the cause of serious discomfort—the most painful part of the operation. On this acount this stage must not be unnecessarily prolonged. The hook is now transferred to the left hand of the operator, and the scissors are taken in the right hand. One blade is slipped between the hook and the sclera behind the tendon, the other passing in the wound in front of the insertion. The tendon is now divided as close to the insertion as possible without actually cutting into the sclera. See Fig. 21. This is generally done by three or four snips; because this does not require so much displacement of the parts, as it does to thrust the scissors all the way beneath the tendon, and divide the whole at one cut. The latter plan, however, may be

safer for the inexperienced operator. With the complete division of the tendon the hook comes forward out from the conjunctival wound, or slips beneath the conjunctiva up to its attachment at the corneal margin.

The wound may now be cleansed and the result inspected. A finger or the handle of the hook being held before the eye, for the patient to fix, is carried to or from the middle line, to show the freedom of movement. The other eye should be uncovered, and the relative positions of the two compared, by noticing the positions of the reflections of the window, or other source of light, on the two corneas.

If the effect of the operation seems less than desired the eye may be fixed by the forceps, catching in the limbus of the conjunctiva; and the hook introduced with the tip turned down and backward to pass behind and below the original point of first introduction, in search of any undivided attachment of the tendon to the sclera below. Any such attachment found should be held on the hook and divided with the scissors as was the main insertion. Then the hook may be again swept back and upwards and drawn forward to discover any undivided attachment in that direction. If no such structure is caught the hook will pass freely forward to the limbus.

To complete the operation the needle is grasped with the needle holder in the right hand and entered half way between the corneal margin and the center of the wound, through the conjunctiva steadied by the fixation forceps. The needle is then carried under the conjunctiva to a corresponding point on the nasal side of the wound, drawn through, and the suture tide with very moderate tension. Blood clots are to be washed away, and the eye closed and covered for a few hours, or until the next day, with a light dressing.

The most frequent and serious complication is excessive *hemorrhage*. This hides the steps of the operation, prolonging it and causing uncertainty as to exactly what is being accomplished. The blood comes either from minute vessels, the necessary oozing accompanying such incisions; or from larger vessels, particularly veins that chance to be located in that portion of the conjunctiva or subconjunctival tissue, or which pass close under the tendon to enter the sclera. The oozing can be almost wholly controlled by the previous instillation of one of the suprarenal preparations. The larger superficial vessels are visible on careful inspection, and may be avoided by limiting or shifting the incision. The conjunctiva and subjacent tissue are so readily pushed aside, that a moderate variation in the position of the opening made in them interferes little with the subsequent steps of the operation. The presence of an unusually large vessel beneath the tendon cannot be

known until it is cut. This is a reason why the tendon should be well included in the hook before attempting to cut it; and why it is safer for the beginner to pass the blade of the scissors entirely beneath the tendon so as to divide its whole width at a single stroke. If these points are attended to it will very rarely be needful to delay the operation on account of excessive hemorrhage.

Perforation of the sclera by the point of the scissors has occurred to skillful and experienced operators. (Derby, H. *Tr. Amer. Ophth. Soc.*, Vol. IV, p. 33.) Knapp ascribed it in his cases to the use of scissors with perfectly sharp points. Czermak (*Die Augenärtzlichen Operationen*, p. 498) says it occurs when the scissors are directed beneath the tendons somewhat obliquely from behind. The pressure of the tendon on the blade thrust beneath it causes its point to penetrate. The danger is avoided by having the scissors parallel to the line of tendon insertion with the convex surface turned toward the sclera. The concavity of the curved scissors fits the sclera more closely, when the instrument is applied exactly upon the eyeball. But with the convexity turned toward the eyeball, the handles are in much more convenient position. And where the tendon is divided by two or three snips the section can be made closer to the insertion with the convexity toward the globe than it can be with the concavity turned to the insertion, and the scissors thrust under the whole width of the tendon to divide it at one cut. If the sclera has been penetrated the division of the tendon may be completed or deferred; but the eye should be dressed and treated as after a cataract extraction.

Multiple insertions of the tendon are rare, yet the possibility of their occurrence should be borne in mind. Wicherkiewicz (*Klin. Monatsbl. f. Augenheilkunde*, Feb., 1907, p. 200) reported a case in which the internal rectus was inserted by two tendons separated from each other by an interval of 4 mm. Sometimes the insertion instead of being an approximately straight line or slight curve, is quite irregular in outline. This liability to such irregularities is the reason for sweeping the hook rather more freely behind the insertion, than would otherwise be necessary. Rarely does the insertion depart from approximately its usual situation. But sometimes tenotomy is attempted upon a muscle that has previously been subjected to the same operation. In such a case the operator will generally find little resemblance to the normal tendon and its insertion in the broad mass of scar tissue; which may be widely attached to the sclera, and also to the orbital connective tissue. Velhagen (*Klinische Monatsbl. f. Angenh.*, 1909, Beilegeheft, p. 19) found the muscle drawn 7.5 mm. back of its original

insertion, with sclera, capsule, muscle extremity and fascia all united by scar tissue.

Effect of tenotomy of internus. Insufficient effect produced by simple tenotomy will generally be met by resort to some modification, or extension of the operation, as described in connection with other forms of operations. Excessive effect should rarely occur if the preliminary study and management of the case are carried out with attention to the details to be mentioned above. If, however, decided turning out is manifest at the close of the operation, a stitch may be placed in the retracted tendon and surrounding tissue, and secured anteriorly as for an advancement. Or the external rectus may be thoroughly stretched; or a thread passed through its insertion and secured to the bridge of the nose, in the manner described by Wilde, to keep the eye somewhat in convergence until the divided muscle has time to reattach itself. It is customary to do tenotomy on the deviating eye—the one having the worse vision. But Bettremieux (*Ann. d'Oculist,* Oct., 1913) urges that it should be done on the fixing eye to produce the most definite effect.

One need not attach great importance to the apparent position of the eyes at the close of the operation, if the degree of squint has been carefully ascertained, and the operation properly planned to correct it before beginning to operate. The effect to be aimed at in any tenotomy for convergent squint is something of an under-correction of the existing squint. It is always to be remembered that the internal rectus is not the only muscle that acts to turn the eye in. The superior and inferior recti, especially their internal fibres, assist under normal conditions; and help still more to produce convergence when the eye has already been turned in, as in convergent strabismus. Under these circumstances the division of the internus producing some diminution of convergence is generally followed by relaxation of the nasal portions of the superior and inferior muscles, and this still further diminishes the turning in.

The alteration to be expected in the direction in the visual axis from simple tenotomy of the internal rectus, varies with the degree of strabismus. In low degrees of convergent strabismus the convergence depends chiefly on contraction of the internal rectus muscle, and simple division of its tendon is likely to produce a change of direction of 2 or 3 mm., 10 or 15 degrees. When the convergence is of very high degree it depends largely on the contraction of the nasal fibres of the superior and inferior recti; and simple division of the internus may produce no perceptible effect.

Sequels and after treatment. The exuberant granulation which the

earlier operators looked upon as an ordinary sequel, is now rarely seen. It probably arose from the leaving of a stump of the insertion uncovered by the conjunctiva. To prevent such a growth is an important reason for dividing the tendon directly at its insertion into the sclera; and also for bringing the conjunctiva together by a stitch at the conclusion of the operation by the open method. Should it arise, the old methods of snipping with the scissors, or touching with silver nitrate are still applicable.

Excessive hemorrhage is apt to be followed by retention of blood in the subconjunctival tissue. An advantage of the open method is that it promotes the free escape of the effused blood. But this advantage is only gained by waiting for the bleeding to cease before introducing the suture. The operation is followed by swelling and hyperemia of the parts involved; that do not wholly subside for several weeks. Ultimately the point of original insertion of the tendon and the sclera behind it, exposed by the retraction of the tendon, can generally be seen through the conjunctiva.

A more important sequel is retraction of the caruncle, which gives the eye a staring look and an appearance of exophthalmos. Actual protrusion of the globe does not occur, unless the suspensory fascia of the orbit has been considerably injured. The falling of the caruncle is guarded against by the conjunctival suture, and by dissecting between the tendon and the caruncle, before raising the tendon to divide it.

Howe (*Tr. Amer. Ophth. Soc.*, X, p. 319) believes that retraction of the caruncle may depend on retraction of Horner's muscle. He has sought to remedy it by tenotomy of that muscle. This is effected by seizing the caruncle with forceps, drawing it towards the cornea, entering a narrow cataract knife at the extreme inner canthus to the nasal side of the caruncle, parallel to the inner wall of the orbit, and cutting both ways to divide all the fibres of the muscle. To prevent immediate union of the fibres the upper and lower ends of the vertical linear wound thus made are brought together by a suture; carried from beyond one extremity of the wound to beyond the other by a small curved needle. The caruncle may also be loosened from the underlying tissues and advanced towards the cornea by a suture resembling one of those used for muscular advancement. But usually in cases of this deformity the advancement of the internus muscle is also advisable; and in doing this the adjoining tissues including the caruncle can be brought forward, as in Critchett's advancement operation.

After treatment. The eye being cleansed at the close of the opera-

tion is usually covered with some form of dressing, as gauze or cotton, held in place by adhesive strips, a roller bandage, or one of the special forms of eye bandage. Operators sometimes permit the eye to go without any dressing. Others keep it closely bandaged for 3 or 4 days. The writer prefers a light dressing retained by adhesive strips, to remain on until the next day. After this the cleansing of the eye by a boric acid, or physiologic salt solution, is all the treatment required.

Variations in tenotomy by the open method. It is stated by Taylor (*Brit. Med. Jour.*, 1887, II, p. 1275) that Graefe usually introduced the hook beneath the upper edge of the tendon, and cut from above. Taylor introduced the hook from below, and then after freeing the point with the snip of the scissors divided the insertion from above downwards thus avoiding all tendency of the tendon to slip off the hook.

Instead of making the conjunctival incision vertical, parallel to the corneal margin, it may be made horizontal, radiating from the center of the cornea. To do this a vertical fold is seized and snipped through horizontally, making an incision 8 or 10 mm. long, the center of which should be placed over the insertion of the tendon. To introduce the hook beneath the tendon the conjunctiva must be pushed aside, upward or downward. The exposure of the insertion is not so complete. But on the other hand this radiating incision is less likely to divide large vessels passing forward toward the corneal margin, and there is much less gaping of the incision, less danger of sinking of the caruncle, and no need to introduce a stitch to prevent this unpleasant result.

Some operators have preferred *to divide the tendon without using the strabismus hook,* notably von Arlt, Schweigger, Fuchs, and Meller (*Ophthalmic Surgery,* Amer. Ed., p. 84). The conjunctival and subconjunctival tissues are incised as for the open method, first described. With the end of the closed strabismus forceps the tissue overlying the tendon is pushed back 3 or 4 mm. from the insertion. The forceps are then opened and made to grasp the whole width of the tendon, as nearly as possible; which is then pulled up from the sclera and divided with the scissors. Having done this, however, most operators use a small strabismus hook to catch up any portion of the tendon remaining undivided, which is snipped through as previously described. By this method a skilled operator can do tenotomy very quickly. But it requires a full-sized incision parallel to the margin of the cornea, to be closed afterwards with a stitch; and is liable to cause more disturbance of adjoining structures than the ordinary use of the hook.

Subconjunctival tenotomy. The instruments required are the same as for tenotomy by the open method, except that a needle and suture are only needed for certain emergencies. The operation consists essentially in dividing the tendon through a small opening, usually not directly over the insertion, but placed so close to the tendon that the opening in the loose conjunctiva can be pulled over the insertion of the tendon; and it is generally so drawn at some time during the operation. The procedure of Critchett (*Lancet*, 1855, Vol. I, p. 507) is still used. It begins by seizing the tissue over the lower margin of the tendon just back of its insertion; and cutting it with the scissors in such a way as to give a conjunctival incision 5 or 6 mm. long and parallel to the margin of the tendon. The deeper tissue is raised with the forceps and the incision carried down to the sclera. The tip of a large strabismus hook is then pressed against the sclera and carried backward and upward beneath the tendon until it can be seen to emerge under the conjunctiva at the upper margin. The hook is drawn forward so as to put the muscle on the stretch and slightly raise the tendon from the sclera.

The points of the strabismus scissors are introduced, closed, within the conjunctival incision; and then slightly opened. One blade is pushed beneath the tendon, between the hook and the sclera. The other blade is pushed in front of the insertion of the tendon, under the conjunctiva. The tendon is then divided at its insertion by two or more snips. If the division of the tendon is complete, and the effect produced satisfactory, this completes the operation. If the effect is not so great as was expected, the hook may be swept around to catch any undivided slips of tendon, and these cut as after the open operation. There is especial liability for the upper fibres of the tendon to slip off before they are divided. It was to guard against such an accident that Theobald (*Amer. Jour. Med. Soc.*, Vol. 63, p. 405) proposed his crochet hook, having a barb on the tip like that of a crochet needle; somewhat like Bolton's instrument (see Fig. 17), but the barb toward the concavity instead of at right angles thereto. Critchett advised, to complete such an incomplete tenotomy, the making of an incision close to the upper border of the tendon, similar to the one that had been made below; and introducing the hook and dividing the remaining part of the tendon from above.

Snell (*Brit. Med. Jour.*, 1887, p. 660) adopted the practice of dividing the whole tendon from above, and reported 100 cases in which the operation had proved most satisfactory. He preferred this plan because the operator could stand behind the patient, who was not compelled to see the instruments; and it caused less sinking of the caruncle,

because the caruncle is more closely associated with the conjunctiva below than above. In case of free hemorrhage he made a counter puncture in the lower part of the conjunctiva. The tendon can be divided through a radial incision in the conjunctiva placed anywhere close to the insertion. The writer has most frequently done it through an opening a little above the lower edge of the tendon. The incision should be differently placed in different cases, chiefly to avoid the cutting of the larger vessels and causing troublesome hemorrhage.

Snellen (*Klin. Monatsbl. f. Augenh.*, 1870, p. 26) picked up the conjunctiva and capsule in a horizontal fold, directly over the center of insertion of the tendon. This is cut with the scissors; making a small vertical incision. The center of the tendon close to its insertion is then seized with the forceps, raised from the sclera and snipped through, making a small *button-hole opening* in the center of the tendon at its insertion. Through this a small strabismus hook is introduced beneath the tendon and turned upward. (See Fig. 22.) That portion of the tendon is raised, the point of the scissors introduced, one blade passed behind and the other in front of the insertion, and the upper half of the tendon divided. Then the hook is turned downward, and the lower half of the tendon divided in the same way. This operation is the basis of the Stevens' operation of partial tenotomy to be described later. It does tenotomy with less disturbance of structures, other than the tendon to be divided, than any other form of operation. For hemorrhage, or to get an increased effect, it can instantly be converted into a tenotomy by the open method.

Tenotomy of the external rectus. Either of the operations above described, as done on the internal rectus muscle, may be done on the externus, with the same instruments and with but little modification of technique. They require the same preparation and after treatment. The field for operation on the externus is more readily accessible. There is less likelihood of being hindered by excessive hemorrhage, no risk of sinking of the caruncle, and no danger of an excessive effect. The insertion of the external tendon is slightly farther back from the cornea. The incision for the open operation may be 7 or 8 mm. from the clear cornea. There is more room for the radiating incision for a subconjunctival operation; and more free space for the manipulation of the handles of the strabismus hook and scissors. Even after an open operation a suture is not essential.

For tenotomy of the external rectus by the *subconjunctival method*, the lids being separated by the speculum, the eye is turned strongly toward the nose. The fixation forceps with their tips separated about 6 mm. are applied to the conjunctiva and brought together so as to

raise a vertical fold 6 mm. from the corneal margin. This fold is snipped with the scissors in such a way as to make a conjunctival incision 5 or 6 mm. long and 4 mm. below the horizontal meridian of the eyeball; the incision being over the lower part of the tendon insertion, and parallel to the lower margin of the tendon. The point of the scissors is then introduced beneath the conjunctiva, and by blunt dissection with the closed scissors, and a few short snips, the more superficial tissue is separated from the insertion of the tendon. The point of the scissors is then turned downward and a similar tunnel carried below the margin of the tendon.

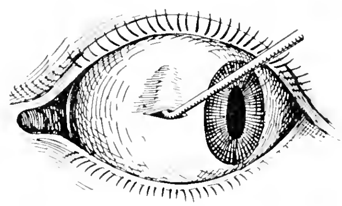


Fig. 22.
Tenotomy by the Subconjunctival Method of Snellen. Upper Half of Tendon Raised on the Hook.

The larger strabismus hook is entered at the incision, and its tip carried downward and backward 4 or 5 mm. It is then turned upward and backward, and the hook swept beneath the tendon. One blade of the scissors is introduced beneath the hook and carried along it as a guide beneath the tendon. The other blade is introduced over, or in front of the insertion of the tendon, in the tunnel opened by blunt dissection. The tendon is then divided at its insertion, care being taken that the upper margin shall not escape from the hook before it is fully divided. Such escape may be prevented by shifting the hook slightly after the lower part of the tendon has been divided in such a way that the tip shall point farther forward above the upper edge of the tendon, the curve of the tip lying beneath the tendon slightly back from the insertion. By slight pressure of the strabismus hook on the conjunctiva after the division of the tendon has been completed the effused blood may usually be expelled. No suture is required. The after treatment is similar to that for tenotomy of the internus.

Tenotomy of the externus produces less effect on the position of the eye than tenotomy of the internus. This has been noticed by operators from the early days of squint operations. There are several reasons for it. Parallelism and convergence of the eyes are attained

and kept up by neuro-muscular effort. Divergence is a passive condition which appears at death, in coma, in profound general anesthesia; or when, on account of blindness, in one or both eyes, binocular vision is given up. This was pointed out by Hansen Grut (*Ophth. Rev.*, Vol. 9, 1890, p. 16). Convergence is a function lately acquired in the process of animal development. Most of the lower animals have their visual axes widely divergent. Hence, when the eyeball is released from the influence of neuro-muscular activity, it is more likely to assume the divergent position. Division of a muscle is followed by some inhibition of the action of its antagonist; and probably of the actions of all the other extrinsic ocular muscles. Tenotomy, therefore, leaves the position of the eyes less under neuro-muscular influence, and more under the control of the connective tissue attachments of the globe. This tendency, with relaxation to take the position of divergence, favors increased effect of tenotomy of the internus, but diminishes the effect of tenotomy of the externus. The shorter contact arc of the internal muscle, almost annihilated by tenotomy, also places that muscle at a permanent disadvantage after such an operation. The contact arc of the externus remains after tenotomy as long as that of the normal internus, so that no limitation of movement need follow from a reduced contact arc. Again the obliques seem more free to act together, as secondary abductors than are the superior and inferior recti to act together as adductors when the respective lateral muscles which they assist have been cut.

The effect secured by a tenotomy of the externus is, therefore, but one-third or one-fourth that obtained by tenotomy of the internus not over 1 mm., or 2 to 5 degrees. The effect at first is greater than this. But it tends to diminish, while the effect of tenotomy of the internus is likely to increase for some weeks after operation. The small ultimate effect produced by tenotomy of the external rectus limits the range of its application to use in heterophoria; or as a last exact adjustment of a slight divergence left by previous operations, or as an adjunct to advancement of the internal rectus.

Tenotomy of the superior and inferior recti. In general the same operations may be done on these muscles as on the lateral recti. The same preparations and after treatment are required. But upon the inferior and superior recti operation is more difficult than on the lateral muscles. This is especially true of the superior rectus, because the insertion of the tendon is farther back from the corneal margin, and there is a general tendency to roll the eye up when it is attacked. It is better to use a lid elevator or a speculum with a solid lid holder, which keeps the lashes out of the field of operation, and lessens the

need of special watchfulness to avoid cutting the lashes or the lid margins. Otherwise the instruments required are the same as for tenotomy of the lateral recti.

For both the superior and inferior recti an operation rather like the subconjunctival tenotomy of Snellen, with a slightly larger opening in the conjunctiva, offers positive advantages. The approach to the field of operation can be made from directly in front, where there is more room for the manipulation of instruments. Then the secondary insertions of the superior and inferior muscles, by which, in part, the movements of the lids are closely associated with those of the eyeball are more extended and more important than the corresponding connections of the lateral muscles. These connections cannot be impaired with advantage; and they are least likely to be disturbed by cutting the tendon each way from its center. It is unnecessary to work through a particularly small conjunctival opening, or to use a suture, for the tendency to gape of a wound perpendicular to the margin of the cornea is very slight, and the wound is habitually well covered by the corresponding lid.

For *tenotomy of the superior rectus*. The upper lid is well raised by an elevator held by the assistant and the eye turned strongly down. The conjunctival incision is made in or to the temporal side of the vertical meridian, commencing 3 mm. above the corneal margin and extending up and back 5 or 6 mm. The incision is carried down to the sclera and tendon, and the episcleral tissue tunnelled, chiefly by blunt dissection, along the whole line of insertion of the superior rectus muscle. Either the tendon is cut at the middle, or the strabismus hook is introduced and the conjunctival wound dragged over entirely to the temporal side of the tendon insertion. The tip, then held in contact with the sclera, is carried beneath the tendon across to its nasal margin. The scissors are entered through the conjunctival opening with one blade in contact with the sclera, the other in front of the insertion, and the tendon is divided at its insertion.

It should be borne in mind that the insertion of the superior rectus is farther back from the corneal margin than the insertion of the other recti muscles, and is more frequently irregular. The introduction of the hook beneath the temporal side of the tendon avoids the risk of catching any portion of the tendon of insertion of the superior oblique. The after treatment is similar to that of tenotomy of the other recti muscles, except that the situation of the wound is well beneath the upper lid where it will be irrigated by the secretion of the lachrymal gland, rendering any dressing quite unnecessary.

For *tenotomy of the inferior rectus* a stop speculum should be used,

and the eye turned strongly up. The operation otherwise resembles that of tenotomy of the superior rectus. The introduction of the hook beneath the temporal side of the tendon lessens the risk of disturbing the inferior oblique, through the attachments that connect that muscle with the inferior rectus. After operation the eye should be dressed and treated as after tenotomy of the internal rectus.

The effect of tenotomy of the superior or inferior rectus is variable and uncertain. Cases have been reported in which the change that followed operation was unexpectedly great and correspondingly annoying. The writer's personal experience would lead him to expect a change of fully 8 to 10 degrees, about one-half that produced by tenotomy of the internus. But no one operator sees many cases suitable for these operations. Knapp (*System of Diseases of the Eye.* Edited by Norris and Oliver, Vol. III, p. 865) thinks the effect produced is distinctly greater than that of tenotomy of the external rectus, but that it tends to diminish in the course of a few weeks. The choice between the different muscles on which an operation might be done, and the particular operation to be done in a given case, will be discussed in the section on general indications for these operations in paralytic strabismus.

Tenotomy of more than one rectus muscle. In high degrees of strabismus the deviating eye may be turned in and up or down, or out and up or down. Tenotomy may be done on one muscle at one time, and upon another at a subsequent date. But if the deviation be fully sufficient to justify both tenotomies they may be made at a single operation. This is distinctly better when it is desirable to obtain a maximum effect. Any two adjoining recti muscles are readily reached through a single conjunctival opening. Suppose a case in which there is a fixed deviation inwards of 25 degrees, and upwards of 12 or 15 degrees.

The conjunctiva is raised between the insertions of the superior and internal recti, in such a way as to make a fold parallel to the corneal margin. This is snipped with the scissors making a cut in the conjunctiva, beginning about 2 mm. from the corneal margin, and extending 6 or 7 mm. in a direction radiating from the center of the cornea. Then the subconjunctival tissue is raised and snipped down to the sclera. With the points of the scissors alternately slightly opened and closed in close contact with the sclera, the tissue is tunnelled from the center of the conjunctival wound to a point slightly back of the upper end of the insertion of the internal rectus muscle, and then to a similar point just back of the nasal end of the insertion of the superior rectus, both points being within 5 mm. of the con-

junctival incision. The tip of a rather large strabismus hook (one projecting 10 mm. from the shank) is then introduced through the conjunctival opening, carried back and down beneath the tendon of the internal rectus, and made prominent beneath the conjunctiva below the lower edge of the tendon. The tips of the scissors are introduced, and the tendon of the internus divided, as in ordinary subconjunctival tenotomy. The hook is then turned up and back under the tendon of the superior rectus, which is divided in the same way. Care should be taken to see that both tendons have been sufficiently divided. The eye is closed and treated as after an ordinary tenotomy.

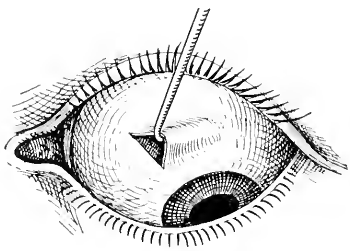


Fig. 23.

Tenotomy of the Internal Rectus and Superior Rectus at one Operation. Showing the superior rectus raised on the hook for subconjunctival division.

Extensions of tenotomy. To do something more than simply divide the tendon or muscle, and so to produce a greater effect than could be obtained by simple tenotomy, and correct higher degrees of strabismus, has been an important undertaking of all who have practiced the operative treatment of strabismus. The first efforts were in the direction of more severe crippling of the muscle tenotomized, by making the incision farther back, even in the belly of the muscle. Some early operators made very extensive separation of the eyeball from the tissues attached to it on the nasal side—so extensive that they may have involved the tendons of the superior and inferior recti. Franz (*London Medical Gazette*, XXVII, pp. 40 and 197) reported a case in which he thought he divided the tendon of the superior oblique, obtaining correction of upward inward deviation which had remained after tenotomy of the internus. But Duffin (*Practical Remarks on the New Operation for the Cure of Strabismus or Squinting.* London, 1840) shrewdly suggests that probably Franz divided the tendon of the superior rectus, which lay more in the direction of the incision described. In 1905 the writer (Jackson, E., *Tr. Sec. on Ophth. A. M. A.*, 1905, p. 73) published the operation described below. It is based on the known participation of the superior and inferior recti muscles

in producing convergence, referred to in the beginning of this section.

Tenotomy extended to secondary adductors. An ordinary tenotomy of the internal rectus is done by the open method. The conjunctival opening should be 8 or 10 mm. long and placed between the insertion of the internus and the corneal margin. From the upper end of the incision the tissues are tunnelled, to just back of the nasal end of the insertion of the superior rectus; by short snips of the scissors, or by a blunt dissection with the point of the closed scissors. In the same way the tissues are tunnelled from the lower end of the incision to just back of the nasal end of the insertion of the inferior rectus.

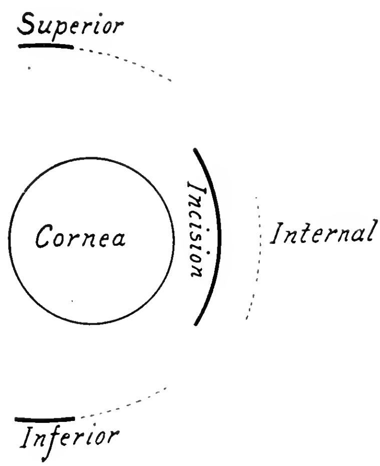


Fig. 24.

Extended Tenotomy of Internus. Relations of the Conjunctival Incision to the cornea and the insertions of the tendons. The parts of the insertions divided in the operation are indicated by dotted lines.

A rather large strabismus hook is passed upward and outward beneath the tendon of the superior rectus, until its tip shows beneath the conjunctiva at the temporal margin of the tendon, making the whole width of the tendon visible upon the hook. The scissors are then introduced, one blade in front of the tendon, the other beneath the hook behind the insertion, until the desired proportion of the width of the tendon is included between the blades. This part of the tendon is then snipped off. The same procedure is practiced on the tendon of the inferior rectus muscle, taking care to divide the same proportion of each tendon, unless there is also some vertical deviation to be corrected. The relations of the tendons to each other and to the conjunctival incision, and the parts of the insertions divided are shown in Fig. 24.

Little additional effect over the simple tenotomy is gained by this operation unless fully half of the width of the superior and inferior tendons has been divided. This amount is what one may aim at in making the first cuts. Then the position and movements of the eyes may be determined by inspection of the corneal reflexes, and by getting the patient to fix the finger tip carried to different parts of the field of fixation. If the effect produced still seems insufficient, the hook must be introduced again under each tendon beyond its temporal margin, and the proper proportion of the remaining width of tendon divided, treating the two muscles alike. *In no case is the whole width of the superior or inferior tendons to be divided.* If this caution is observed the vertical movements of the eye will be noticeably impaired even temporarily. The division of the superior and inferior tendons may safely be carried so far that there remains only a narrow band to hold the strabismus hook, two-thirds or three-fourths of the width of the tendon having been cut off.

For the correction of high convergent strabismus by tenotomy extended to the secondary adductors, the object aimed at should still be an under-correction. At the close of the operation there should still remain convergence one-fourth or one-sixth as great as at the beginning. For a convergence of 50 degrees one should aim to leave about 10 degrees of convergence which will be gradually reduced before the eyes will reach their permanent condition of balance.

A similar operation of *complete tenotomy of the external and partial of the superior and inferior* muscles may be practiced, dividing the temporal portions of the latter. Generally this will be done in connection with advancement of the internus, for extended tenotomy, like simple tenotomy of the externus, gives a relatively slight effect.

In view of the cases reported by the earlier writers, and mentioned even by writers of the present day, illustrating the danger of unsightly protrusion of the eyeball after tenotomy, it has been feared that *exophthalmos* would be likely to follow such extensive division of the tendons of the recti. But it does not. In the writer's cases on which such operations were practiced, no consequent protrusion has been produced. The series is not a large one, but it is sufficient to show that protrusion is not usual. In no single case has any noticeable exophthalmos followed. The prominence of the eye has been measured before and after operation in several cases in which the lateral tendons have both been cut (one of them being advanced); and two-thirds or three-fourths of the superior and inferior tendons severed at the same operation, without any change in the prominence of the globe. Exophthalmos may occur after tenotomy, even so much as 2

or 3 mm. of protrusion. But in these cases there is evidence that the connective tissue structures other than the tendon have been extensively interfered with. The conclusion seems warranted that it is *disturbance of Tenon's capsule, and not division of the tendons that causes protrusion.*

The cases yet submitted to extended tenotomy are too few to establish the amount of change in the direction of the eyes that may thus be obtained. But in moderate strabismus it seems to be almost double the effect obtainable by simple tenotomy; and in strabismus of very high degree many times greater than we expect of simple tenotomy. Whether any such effect would be produced by tenotomy of the internal rectus done at one time, and partial tenotomy of the superior and inferior recti done at another time, is doubtful. The latter operation, with stretching of the internus, has produced very little permanent effect.

A very undesirable effect of tenotomy is the subsequent deviation of the eye in the opposite direction. But it has not occurred after the extended tenotomies. Apparently when the relation of the secondary adductors is altered by the operation, a later change in them is less likely to occur.

Extensions of tenotomy to the capsule of Tenon should be replaced by advancement of the opposing rectus. They are described here as of chiefly historical interest. They consist of extending the incisions from the tendon to neighboring connective tissue structures. One of the best was described by Liebreich (*Gazette des Hôpitaux,* July 25, 1867). Before dividing the tendon the scissors were carried between the conjunctiva and capsule back to the plica semilunaris; and then on toward the canthus, separating the plica and caruncle from the deeper structures connected with the eyeball. This was to prevent any sinking or disturbance of the caruncle by subsequent retraction of the tissues divided. Then after doing tenotomy, very much as done subconjunctivally by Critchett, the incision was extended vertically upward and downward, dividing the capsule to the extent necessary to produce the desired effect. By this operation Liebreich claimed to be able to correct about twice as much deviation as by tenotomy alone; and by one operation done on each eye, to cure the extreme cases of convergent strabismus.

Thread operations to increase the effect of tenotomy or advancement are done to supplement the effect by controlling the position of the eye during the first few days of healing. The especial technique of these supplementary operations was first brought out by Wilde, in the description previously quoted. The thread is attached to some firm

structure apart from the eye, to which the eyeball is thus anchored until the stitch begins to loosen. Graefe (*Arch. f. Ophthalmol.* iii, Pt. I, p. 177) reported a case in which he cut off both the internal and the external tendons; and without reattaching either to the eyeball, anchored the globe in such a position that the cicatricial reattachment of the tendons gave a satisfactory change in the direction of the visual axis. But his success does not seem to have been such as to lead him to persist in this operation, or to cause others to try it.

Knapp (*Tr. Heidelberg Congress,* 1865) passed the suture which anchored the eye through the lids. For convergent squint he secured a firm hold at the outer side of the cornea and carried the thread from within outward through the skin beyond the external canthus. For extreme divergent squint the thread was fixed at the nasal side of the cornea and passed through the skin near the inner canthus. But only the cases reported in his original paper have been placed on record.

Of recent years thread operations have been done to supplement the effect of tenotomy or advancement. They have been especially described and advocated by Gruening (*Tr. Amer. Ophth. Soc.,* Vol. VI, p. 165) and by Marple (*Arch. of Ophth.,* 1903, p. 280). They are chiefly applied to cases of external strabismus. A stitch is firmly fixed in the conjunctiva at the nasal side of each cornea, after tenotomy of both external muscles. The ends of this suture are left long and secured over a bit of absorbent cotton on the bridge of the nose, coupling the eyes in a position of strong convergence, which is kept up for 24 hours beneath a binocular dressing. Care must be taken to see that the threads do not press upon the edges of the lids when normally closed.

To maintain sufficient outward rotation of the eye after advancement of the externus, Gifford (*Ophthalmic Rec.,* Vol. 25, p. 124) inserts a suture as shown in Fig. 25. He uses black silk suture, size D, with two needles. The internus is seized and the suture first passed through it. Then each end is passed through the free border of one lid, the eyeball drawn outward, till the insertion of the internus is opposite the point the lids are perforated, and the suture tied just tight enough to bring the lids down on the surface of the globe. The stitch is removed in five to seven days.

Operations to weaken a muscle without completely cutting off its tendon, partial tenotomy. This is done only for heterophoria and has been extensively practiced and advocated by Stevens (*Functional Nervous Diseases.* New York. 1887). For his purposes he (Stevens, G. T., *Motor Apparatus of the Eyes.* Philadelphia, 1906, p. 340)

found the instruments in ordinary use for operations on the ocular muscles too clumsy, and devised more delicate ones. The forceps end in fine teeth, projecting slightly to facilitate the seizing of firm tissue, like the sclera or the tendon close to the scleral insertion.

The scissors have their blades narrowed near their tips to facilitate their introduction through a small opening. The strabismus hook is smaller than those commonly employed, the shank ½ mm. in diameter and the hook projecting only 5 mm. from the line of the shank. In Stevens' operation the part of the tendon divided is the central portion directly at its insertion. The anatomic effect of tenotomy of the central part of the tendon, while the margins are left intact, is indicated diagrammatically in Fig. 26. The breadth of the insertion remains unaltered and the secondary functions of the muscle practically unchanged. On the other hand division of one side of the

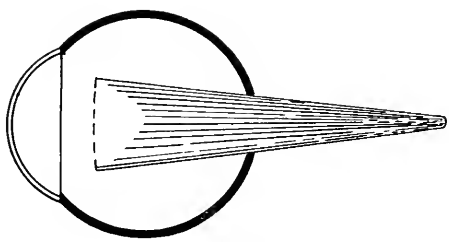


Fig. 25.

Effect of Partial Tenotomy where the Central Portion of the Insertion is Divided. The divided fibres are retracted.

insertion as indicated in Fig. 27 produces some alteration in the secondary functions of the muscle.

For instance, division of the nasal half of the tendon of the superior rectus will permanently lessen its power to assist in the adduction of the eye. Division of the temporal part of its insertion will, on the other hand, tend to make the superior or the inferior rectus more of an adductor; and either of such partial divisions must affect the tendency of the muscle to cause intorsion or extorsion. Such a partial tenotomy was suggested by Savage (*Ophthalmic Myology*. Nashville, 1902, p. 160) for the purpose of thus altering the plane of action of a muscle. Stevens originally desired to limit the effect of his operation to diminution of a single function of the muscle. His later operation of "extendo-contraction," intended to alter its action, will be described later.

Partial tenotomy of the central portion of the tendon of either of the recti muscles is begun as the Snellen operation for complete te-

notomy, care being taken to make but a very small opening in the conjunctiva, subconjunctival tissue and center of the tendon, at its insertion. The small strabismus hook is then passed through the opening and turned toward one-half of the tendon which is drawn on and raised slightly from the sclera. The fine-pointed scissors are introduced through the conjunctival opening, with the tip of one blade behind the insertion, and in close contact with the sclera. The tip of the other blade is carried in front of the insertion, also in close contact with the sclera. What is deemed a sufficient portion, usually two-thirds or three-fourths of the half insertion, is then divided, care being taken not to sever the tendon all the way to its margin. The scissors are now withdrawn. The hook (with its handle and shank perpendicular to the surface of the sclera to cause the least disturbance of tissue) is turned so that the point passes beneath the other half

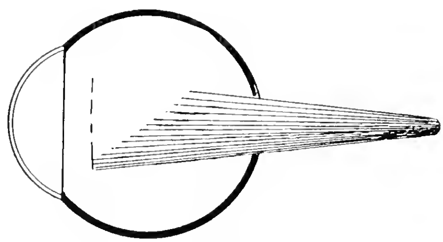


Fig. 26.
Partial Tenotomy where One Side of the Tendon is Freed from the Insertion and retracted.

of the tendon. This is similarly raised, and an equal proportion of this side of the tendon divided, with the same care not to divide the insertion all the way to the edge of the tendon. The scissors are then laid aside and the hook used to estimate the amount of insertion left undivided. First the strand at one edge of the tendon is drawn upon, then at the other edge. If the remaining strands show the same firm resistance as the whole tendon showed to start with, no perceptible effect will be produced by the operation, and more tissue must be divided. If the strand at one edge of the tendon shows less resistance than the other, it should be let alone and the other snipped until the resistance of the two appears to be just equal.

The resistance to the advancement of the hook toward the corneal margin should never be wholly overcome. When it is perceptibly lessened, the balance of the ocular muscles may be tested to determine if sufficient effect has yet been produced. If a greater effect is desirable, the hook is to be introduced again and more fibres divided at

each edge of the tendon, care being exercised to keep the resistance of the edges equal. The effect of the operation can also be increased by rather forcible stretching of the edges left undivided. Where the effect produced is still insufficient, the operation can be carried over into a complete tenotomy.

Partial tenotomy by division of the central fibres was done by Smith (*Arch. of Ophth.*, Vol. XXII, 1893, p. 16) by raising the tendon, entering the point of a keratome at its center, and pushing forward until enough fibres were severed. Partial division has also been practiced by dividing both edges of the tendon at its insertion and leaving the central fibres intact. This method is less serviceable than division

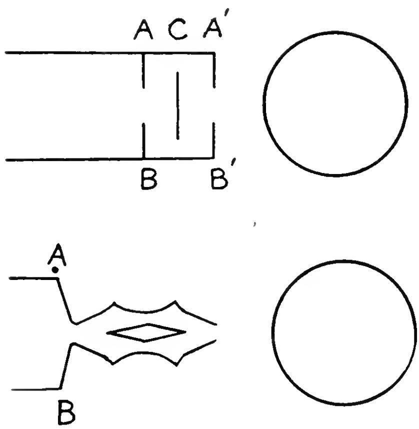


Fig. 27.

Partial Plastic Tenotomy of Verhoeff. The Upper Diagram Shows the Points A B, A' B', and C at which the tendon is partially divided. The lower diagram shows how the tendon becomes lengthened by giving way after the operation.

of the central portion. The firm central fibres do not give, and no perceptible effect is produced, until almost the whole width has been severed. Then there is a sudden giving way with perhaps the production of the effect of a complete tenotomy. Then, too, the division of the lateral fibres causes a loss of the broad insertion of the tendon, which becomes attached to the eyeball by a narrow insertion, sacrificing accuracy and steadiness of fixation.

Plastic tenotomy or division of different fibres at different distances from the eyeball. This has been proposed by Verhoeff (*Klin. Monatsbl. f. Augenh.*, 1903, p. 234) and advocated by Todd (*Trans. Sec. on Ophth. Amer. Med. Assoc.*, 1907, p. 234, and *Oph. Rec.*, v. 23, p. 628) and cases favorably influenced by the procedure were published by the latter. Verhoeff made the partial division of the tendon as shown in

Fig. 27. The lateral fibres were divided at A B some millimeters back of the insertion, and at A′ B′ at the insertion. (Upper diagram.) Between these the central fibres were divided, as shown at C. The effect to be produced by this operation is shown in the lower diagram. The tendon is elongated and weakened.

Todd did not disturb the insertion of the muscle. But he divided one-half the fibres from one edge, a short distance from the insertion, and divided the other half of the fibres from the other edge of the tendon, a little farther back from the insertion. The same fibres may be divided at more than one point. The effect expected from such an operation is shown in Fig. 28.

The upper part of the figure shows the place for division of each part of the tendon in solid lines. The lower part shows the pulling

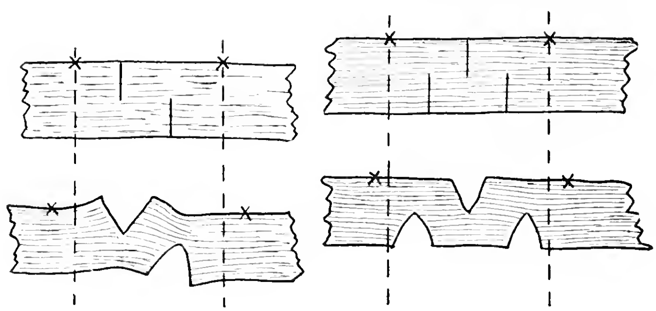


Fig. 28.

Partial Tenotomy by Lateral Incisions. (Todd.) The Upper Diagrams Indicate two methods of placing the incisions. The lower diagrams show how lengthening of the tendon takes place. The greater distance between the crosses below shows the amount of lengthening.

apart of the divided fibres. The broken perpendicular lines are for purposes of comparison. The crosses indicate the same points of the tendon before and after operation, showing the elongation by their separation below. Harman (*Ophthalmoscope*, v. 11, p 74) found that the two incisions caused a vertical deviation, the eye turning in the direction of the cut nearer the insertion. But when he made two cuts on one edge and one between on the other edge, no vertical deviation was caused. It should be noticed that in these operations all the fibres of the tendon are divided, some at one distance from the insertion, some at another. The method of Ziegler (*Trans. Sec. on Ophth. Coll. of Physicians of Philadelphia*, Nov. 18, 1910) is to divide each lateral third of the tendon back from the insertion; and then at the insertion to gradually divide the central portion, testing from time to time the effect produced.

After any of the operations for partial tenotomy it is customary simply to cleanse the eye, and leave it unbandaged. Quiet should be enjoined, and the use of a non-irritant collyrium prescribed. But the eyes may be used some from the first.

Elongations of tendons by division and suture. This was proposed by Stephenson (*Tr. Ophthal. Soc., United Kingdom,* Vol. XXII, p. 276) in 1902, and by Landolt (*Arch. d'Opht.,* Jan., 1905) in 1905. The general plan is to divide completely the tendon by an oblique or a step-like incision; and then to unite the ends by one or more sutures, in such a way as to leave the origin and insertion of the tendon farther apart. Different ways in which this may be accomplished are shown in Figs. 29 to 31.

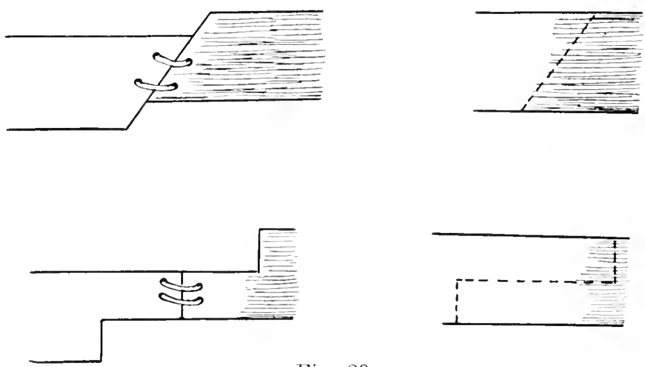


Fig. 29.

Stephenson's Method of Lengthening the Tendon by Step-like or Oblique Incision and suturing.

These are open to the theoretical objection that there would be danger of the bad effects of a lateral displacement of the tendon. But this danger may be avoided by a tongue-shaped division of the tendon, as suggested by Grimsdale (*Chief Operations of Ophthalmic Surgery.* London, 1904, p. 7). See Fig. 31.

Stephenson (*Lancet,* 1905, v. II, p. 883) also suggested complete division of the tendon and the introduction of a suture between the retracted ends as shown in Fig. 32, the suture becoming the basis of scar tissue which should lengthen the tendon. Stephenson at the time of his original communication exhibited cases successfully operated on. But no extended studies of the actual effects of such operations have since been published.

Tenotomy of the oblique muscles. The oblique muscles are inserted on the posterior segment of the eyeball; the superior oblique passing beneath the superior rectus and the inferior oblique under the inferior

rectus. It seems not practicable to divide the tendon of either at its insertion, without serious danger of a disturbance of related parts. Tenotomy of one of these muscles is therefore a totally different operation from tenotomy of either of the recti muscles.

The inferior oblique is divided for paralysis of the superior rectus with fixation with the paretic eye, and consequent excessive contraction of the inferior oblique of the fellow eye; or for paralysis or paresis of the superior oblique with secondary deviation by the inferior oblique of the same eye (Duane *Archives of Ophth.*, v. 45, p. 33) is most readily accessible at its origin; and is there least involved with other structures liable to be damaged by operation. This was pointed out by Landolt (*Arch. d'Ophtalmol.*, v. 5, p. 402), who in 1885 suggested

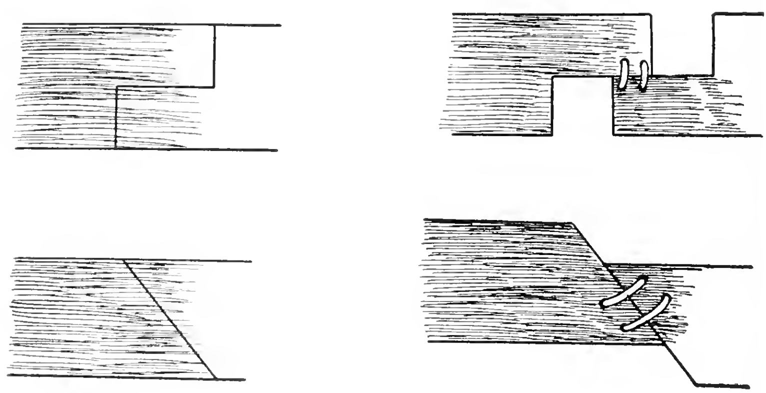


Fig. 30.
Modifications of Tendon Lengthening Suggested by Landolt.

the operation of dividing it at this point. An incision 10 or 12 mm. long is made at the lower inner margin of the orbit, parallel to the edge of the orbit; and carried through the skin, orbicularis muscle and orbital septum. A vertical line dropped from the supra orbital notch will indicate the position. Bleeding is stopped, and the edges of the incision retracted until the bone and the origin of the muscle are seen. The latter is to be recognized by its red color and the direction of its fibres passing obliquely outward, upward and backward. The muscle is gathered up with a strabismus hook, or seized by forceps; and divided as close to its origin as possible, either by scissors or a bistoury. The rolling up of the eye when the strabismus hook is drawn upon indicates that the muscle has been caught by it, as pointed out by Posey (*Ophth. Rec.*, vol. xvii, p. 346 and *Archives of Ophthalmology*, vol. xlv, p. 137).

Tenotomy of the superior oblique can be done at the most superficial part of the tendon in the region of the pulley. Complete division may be justified to remedy the turning down and out of the eye after paralysis of the oculo-motor nerve. The object would be, not merely to weaken the influence of this muscle on the position of the eyeball, but rather to destroy that influence altogether. This will be more certainly accomplished by excising a portion of the tendon, as the writer has done on the cadaver, but not on the living patient.

Fig. 31.
Grimsdale's Tongue-like Incision for Tendon Lengthening.

The nasal portion of the upper lid is raised by an elevator or strabismus hook, or a sharp hook held by the assistant. With the eye turned strongly down and out, the conjunctiva is seized and a radiating incision made, starting 10 mm. up and in from the corneal margin, and extending toward the pulley far enough to divide the retrotarsal fold, up to where the tissues of the lid are attached to the orbital periosteum. The incision is made into the deeper tissues, and then extended by blunt dissection with the points of the closed scissors,

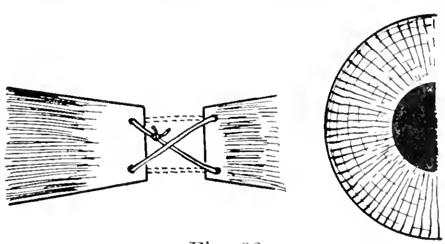


Fig. 32.
Stephenson's Method of Lengthening a Tendon by Dividing and Introducing a silk suture between the cut ends.

with sponging and careful inspection of the structures laid bare, until the pulley and the tendon of the superior oblique are recognized. The exact position of the pulley can usually be ascertained before making the incision, by the tip of the finger pressed into the upper inner angle of the orbit. The tendon is exposed from the pulley toward the eyeball and divided.

The exposure of the pulley can also be accomplished by an incision from the skin surface at the upper inner angle of the orbit, as pro-

posed by Dransart (*Bulletins et Mémoires de la Société francaise d'Ophtalmologie,* 1907, p. 395) for the grafting of the tendon of the oblique upon the external or inferior rectus.

Complete abolition of the influence of the superior oblique may be secured by excising a part of the tendon 5 or 10 mm. in length extending from the pulley toward the eyeball.

Advancement operations differ from each other as to whether the muscle is advanced upon the eyeball, along with the other tissues with which it is related (musculo-capsular advancement), or whether the attempt is made to separate the muscle from related structures and bring it forward alone. They differ also as to whether the sutures used to secure reattachment are introduced simply into the episcleral tissue, or whether they are made to take hold of the firm tissues of the sclera, or the stump of the insertion of the advanced muscle. Then

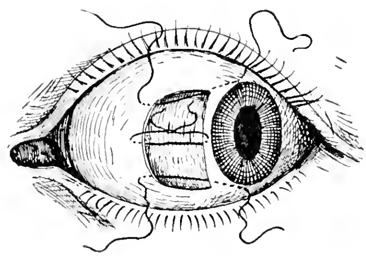


Fig. 33.
Critchett's Method of Advancement. Tissue Excised and Sutures Introduced Ready to Tighten.

an indefinite variety of operations is produced by the use of one, two, or more sutures; and by the different ways in which these sutures have been placed or tied by different operators. The attempt to designate by the proposer's name each variation in the mode of performing an advancement operation is a source of confusion. Operations for the shortening of a muscle by exsection of a part of its tendon, or folding the tendon, "tendon tucking" or "reefing" are to be classed with advancements. It is of practical importance whether an advancement operation is done without other disturbance of the muscular attachments of the eyeball, leaving the advanced muscle to contend with the unhampered activity of its opponents; or whether by over-stretching or tenotomy, its chief opponents have been temporarily weakened or rendered powerless in a combined operation.

Advancement of muscle with capsule. The earliest form of advancement that remains today a valuable practical procedure, was done to remedy a congenital divergent strabismus of high degree, by Critchett,

and described by Bader (*Royal London Ophth. Hosp. Rep.*, Vol. I, p. 254) in 1858. An incision was made through the conjunctiva parallel to the inner edge of the cornea. "The conjunctiva, internal rectus, etc., were dissected off the sclerotic towards the inner canthus; and an oval piece of the flap being excised the wound was united by sutures, three in one eye and four in the other eye. The sutures had been drawn in before the incision was completed; they were removed in a week; no swelling or other bad result followed the operation; a very slight internal strabismus of either remains." This operation was subsequently described with more detail.

Jessop (*Manual of Ophthalmic Surgery and Medicine*, p. 360) does not divide the insertion of the tendon until he has passed one suture through the center of the tendon, tied it tightly in a knot, and carried it through the episcleral tissue, bringing it out through the conjunctiva 1 mm. from the cornea. Then the tendon is cut away from the insertion. Additional sutures introduced at its upper and lower margins are anchored above and below the cornea.

The sutures were introduced by Critchett only into the episcleral tissue, and the externi being for the time rendered inefficient by previous tenotomy, the effect was all that was desired. But greater certainty of securing a definite change in the direction of the eye is to be had by passing the stitch into firm scleral tissue. The operation finally preferred by H. D. Noyes (*Text-Book on Diseases of the Eye.* Ind. Ed., p. 171), was essentially that described above, with these modifications. He introduced the sutures into the sclero-corneal junction using fine needles sharpened until they would penetrate as readily as a discission needle. Conjunctiva, capsule and tendon were all grasped with fixation forceps, which were clamped upon them. The needle was then thrust through from conjunctival to scleral surface and the redundant tissue removed before drawing through the suture. After the three needles had thus been introduced into the flap, the sutures were drawn through this; and the needles made to penetrate the sclero-corneal tissue at the limbus. This is also the advancement operation described by Meller (*Ophthalmic Surgery*, Amer. Ed., p. 86) except that he makes the track of the needles in the superficial scleral tissue parallel to the corneal margin.

Advancement of all tissues with one scleral stitch is the operation preferred by the writer for divergent strabismus of high degree. A curved incision in the conjunctiva and episcleral tissue is made, 10 mm. long and concave to the cornea. The flap toward the canthus is held up and dissected free from the sclera by snips of the scissors. The dissection is first to be made a little above or below the insertion

of the internus, until one blade of the Prince advancement forceps can be slipped beneath the tendon, back from the insertion almost as far as it will be necessary to place the suture. The other blade of the forceps is pressed on the surface of the conjunctiva, so that the whole mass of tissue to be advanced is caught between the blades, which are closed upon it. With the flap thus held the insertion of the tendon, and all other adhesions of the flap to the globe, are divided by snips of the seissors. The flap can then be drawn forward into its desired relation with the eyeball; and the position of the suture necessary to retain it there, and the amount of tissue to be removed, decided on.

The finest, sharpest curved needle is then passed through the flap from the conjunctiva to the scleral surface, back of the blades of the advancement forceps and about 2 mm. above (or below) the center of the tendon. The needle is then passed into the sclera, parallel to the corneal margin and 1 mm. from it; in such a way as to take a firm hold in the sclera without passing through it. It should include one-fourth or one-third the thickness of the sclera; and the points of entrance and emergence should be 3 to 4 mm. apart. If at the first attempt the needle cuts or pulls out of the firm tissue, it should be introduced a little deeper and a little farther back from the cornea. The needle is then passed beneath the flap and through it from the sclera to the conjunctival surface, back of the blades of the forceps, opposite the original point of entry, and 2 mm. below (or above) the center of the tendon; that is 4 mm. from the first entrance. See Fig. 34. The flap should be drawn forward, and the suture tied. If there remains redundant tissue this may be trimmed away, generally including that squeezed by the forceps.

Generally the above suture is all that is necessary, and upon it is to be placed the chief reliance for the success of the advancement. If there appears a tendency of the conjunctival wound to gape near its upper and lower angles; or if the tissue seems to be much dragged toward the central suture, with a tendency to narrow the new attachment of the tendon to the eyeball, additional sutures may be placed above and below the first one. To introduce such a suture thrust one blade of the forceps beneath the flap, and raise the tissue from the sclera. The needle may be rather larger than for the first stitch and carrying thicker silk. It is thrust from the conjunctival to the scleral surface of the flap; then carried under the conjunctiva above (or below) the cornea, close to its margin, almost to its vertical meridian, but without any attempt to enter the sclera. This suture should be so placed that beside closing the conjunctival wound it will tend to spread the end of the tendon and secure as broad an attachment as possible

for it in its new position. The position of the sutures at the close of the operation is shown in Fig. 35.

The after treatment consists in keeping both eyes closed for the first day with a light dressing, cleansing the eye once or twice daily, and continuing the dressing on the operated eye for four or five days. The sutures should remain from four to eight days. Early removal of the stitches is indicated when the effect seems likely to be excessive, or when profuse conjunctival discharge develops.

Advancement of the external, superior or inferior rectus muscle may be performed in the same manner. But for the superior and inferior muscles, in most cases, one of the operations to be presently described, dealing with the tendon alone, will be preferred. Essentially the same operation has been described by Jocqs (*Clin. Ophtalmol.*, 1904, p. 206); and Motais (*Bull. et Mem. de la Soc. francaise d'Ophtalmol.*, 1906) has used two such sutures, one to secure the upper and one the lower portion of the tendon.

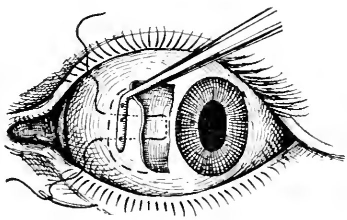


Fig. 34.

Advancement with Single Scleral stitch. Tissue held by forceps and scleral stitch placed ready to tighten, and later cut away tissue at the broken line.

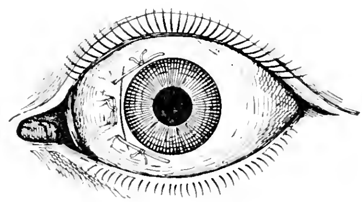


Fig. 35.

Advancement with Scleral Stitch in centre, and superficial stitches above and below, at completion of operation.

Advancement with partial isolation of tendon was first described by Agnew (*Tr. Amer. Ophth. Soc.*, 1866, p. 31). He made a horizontal incision beginning 2 mm. from the nasal margin of the cornea, and extending to the semilunar fold. This was carried down to the sclera and muscle to be advanced. A strabismus hook, with an eye drilled in its free extremity, and armed with waxed silk, was then swept beneath the upper edge of the tendon, going far enough back to include every straggling band; and the ligature so introduced was tied close to the insertion in the sclera. A free tenotomy was done on the opposing external rectus muscle. The tendon to be advanced was raised by the ligature placed around it, and was divided at its insertion. Two retentive sutures were now introduced through the tendon far enough back to produce the advancement desired, and to take a firm hold

rather deep in the muscle. The needles were passed from the conjunctival to the scleral surface of the tissues, one near the upper, the other near the lower margin of the tendon. After these were placed, the end of the tendon included in the ligature was cut off. (The tendon can be more conveniently held by the Prince's advancement forceps.) Then each needle was carried beneath the conjunctiva, above or below the cornea respectively, so as to take a firm hold in the sclera and emerge about 2 mm. from the corneal margin in the vertical meridian. Both sutures were drawn up before either was tied.

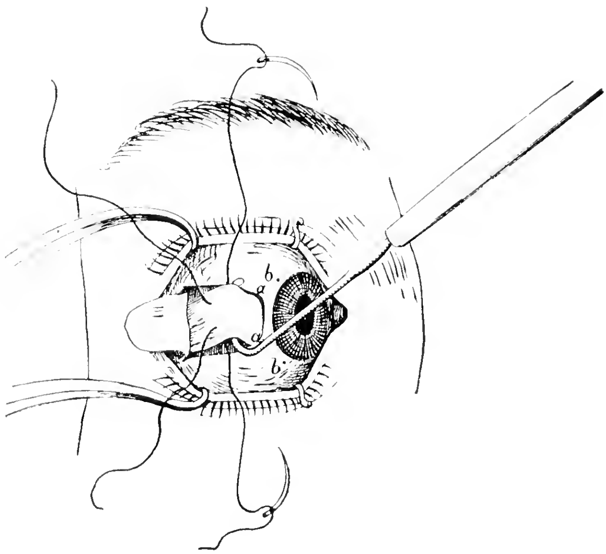


Fig. 36.

Advancement with Partial Isolation of the Tendon. Method of Landolt. Showing the sutures placed in the tendon; but not yet introduced beneath the conjunctiva at a, to be brought out at b, above and below the cornea.

In doing this operation Carter (*Practical Treatise on Diseases of the Eye.* Edited by Green, p. 438) used cat-gut retentive sutures, which were left in permanently.

In 1878 Landolt (*Compte rendu de sa Clinique pour L'Année,* 1878, p. 16) wrote his first paper on advancement. His operation would now be regarded rather as an advancement of the insertion of the tendon. It is the prototype of many of the recent modifications of advancement.

A semi-circular flap of the conjunctiva, down to the capsule of Tenon, is dissected up over the insertion of the muscle to be advanced. See Fig. 36.

The anterior extremity of this flap begins almost at the corneal margin. It is broad enough to expose freely the whole width of the tendon. The flap is turned back, and the strabismus hook passed beneath the tendon, which is raised on it. Or to secure the whole width of the tendon and to give better access to it a second hook may be passed beneath it from the opposite side. The hook is confided to the assistant. Two sutures are then passed from the conjunctival toward the scleral surface, through the capsule and tendon. These are placed at the junction of the middle and lateral thirds of the width of the tendon, and far enough back to secure the necessary advancement of the insertion. These sutures are brought out beneath the edges of the tendon, as shown in Fig. 36.

The four threads may now be taken in the left hand, the tendon drawn away from the eyeball, the blade of the scissors slipped beneath it, and the tendon divided in front of the position of the threads. If the effect of the operation is to be but slight the tendon is divided at its insertion. If a greater advancement is desired the tendon may be divided farther back towards the sutures, and the stump so left cut off at the insertion.

The placing of the sutures in their position of anchorage is the most delicate part of the operation. The point of the needle is introduced at a (or a′) and carried to b (or b′) through the firm episcleral tissue at the junction of the conjunctiva and cornea. Using a sharp needle, Landolt (Graefe-Saemisch *Handbuch der Gesamt Augenh.,* 2nd Ed., Pt. 91, p. 249) claims that in children this is not difficult; because the conjunctival tissue is firm and the sclera is soft. But in adults in whom the sclera has become hard and the conjunctiva thin and loose, it is more difficult to secure a firm anchorage. When it is not secured at the first attempt, the needle may be again entered under the conjunctiva and an additional mass of tissue included until a firm hold is secured.

The threads having been introduced, the eyeball is brought into proper position and the muscle drawn forward to the margin of the cornea with the fixation forceps. The threads are then tightened, care being taken to secure the same tension of each suture. To ensure this they may be drawn upon alternately; and one tied with a temporary knot until the right degree of tension is reached, when the permanent knots are to be tied. To avoid confusion Landolt makes one suture of black, the other of white silk.

Even where but one has been operated on, both eyes are kept bandaged for 5 or 6 days, being cleansed and dressed but once in the 24 hours. The stitches are removed at the end of 5 or 6 days. The

condition to be aimed at is an over-correction, during the period that the stitches remain in.

Axenfeld's operation, described by Mohr (*Zeits. f. Augenh.*, v. 24, p. 357), includes a third stitch at the middle of the tendon. These all include firm scleral tissue at the limbus, above, below and at the proximal margin.

Advancement with anchor stitch. The first operation of this sort was described by Prince (*Ophth. Review*, Vol. 6, p. 249). The anchor or pulley suture *a* is introduced 1 mm. from the corneal margin deep enough to take hold of the firm scleral tissue. The conjunctiva and subjacent tissue are divided parallel to the corneal margin, as shown in Fig. 38.

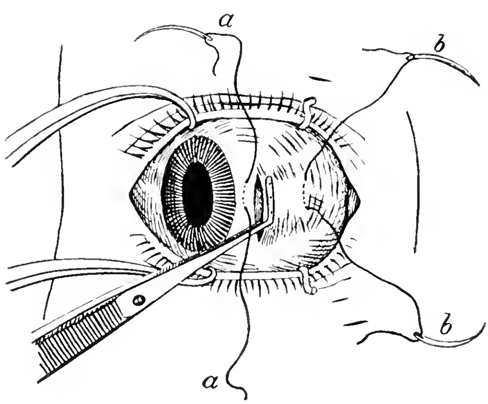


Fig. 38.
Advancement with Pulley Stitch. (Prince.) Stitches Placed, a Pulley, and b tendon suture.

One branch of the advancement forceps is introduced beneath the tendon and the other closed upon it, seizing both tendon and conjunctiva, with all intermediate tissues in their normal relations. The insertion of the tendon is then divided. The loop suture *b* is introduced by the needles at each end, which are passed beneath the tendon from its scleral surface out through the conjunctiva. The location of this suture is governed by the amount of advancement required. The tissues grasped by the forceps are then excised to about 2 mm. in front of the suture *b*. The suture *a* is tied over one end of the suture *b*, becoming a pulley. The suture *b* as shown in Fig. 39 is then drawn upon, and tied in a bowknot. Subsequently the tension of this suture may be increased or diminished, if such change is required to secure the effect aimed at. It is then tied in a permanent knot.

Two stitches placed somewhat like those of Prince have been used by Hulen (*Tr. Sec. on Ophth., Amer. Med. Assn.*, 1910, p. 225), who, however, ties them differently. He places each thread double; and uses one pair of the sutures to draw the eye into position, while the other pair are tied together. The first may be left in position temporarily; and tied for a better adjustment if necessary, the other stitch being cut and removed. Hardy (*Amer. Jour. of Ophth.*, Vol. 32, p. 353) has adopted this procedure, but using the muscle stitch of Worth with firm anchorage in the limbal tissue.

Williams' (*Brit. Med. Jour.*, 1887, Vol. 1, p. 874) single suture advancement begins with a radiating (horizontal) incision over the middle of the tendon to be advanced, which is extended from near the cornea to near the canthus. The tendon or muscle thus laid bare is

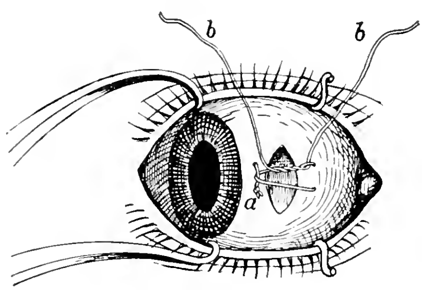


Fig. 39.
Pulley Advancement (Prince) with Tissue Excised. Pulley Stitch a Tied, and tendon stitch b ready to tighten.

raised and isolated on the strabismus hook. The suture is introduced beginning near the corneal margin rather lower than the edge of the tendon. It is carried beneath the conjunctiva, brought out of the wound, and passed back and forth through the tendon parallel to the corneal margin, after which it is brought under the conjunctiva to the point opposite its original entrance. Grimsdale and Brewerton (*Text-book of Ophthalmic Operations*, p. 33) suggest that it should be dipped into firm tissue at its point of first entering the conjunctiva, and also just before its final emerging. The suture thus placed is shown in Fig. 40. Loops of suture are left on either side of the tendon, which are drawn out of the way until the tendon has been separated from the sclera. Then the parts are drawn into the desired position and the suture tightened and tied. The tying of the suture tends to close the conjunctival wound, and bring folds of conjunctiva over to the cornea. These folds tend to protect the cornea from the suture and disappear

when the latter is removed. The conjunctival wound is closed with a suture. The sutures are removed about the eighth day.

The operation first described by Beard (*Amer. Jour. of Ophth.*, 1889, p. 74) seems to have been worked out independently by Ferguson (*Tr. Ophth. Soc., United Kingdom*, Vol. XVII, p. 336) and Howe (*The Muscles of the Eye*, Vol. II, p. 354). The conjunctiva is raised in a vertical fold back of the insertion of the muscle and snipped over the center of the tendon. The incision thus begun is carried forward to the corneal margin and through the episcleral tissue, forming a furrow "whose bottom is the naked sclera and along which the cut tendon is to slide." The tendon is raised on a medium sized strabismus hook, placed close to the insertion and held by an assistant until

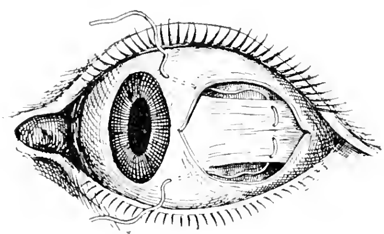


Fig. 40.

Single Stitch Advancement of Williams. Tendon exposed and suture placed before the insertion of the tendon has been divided.

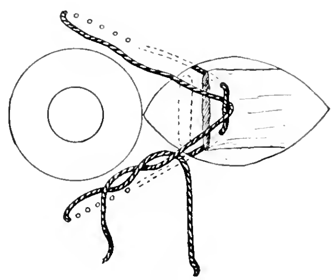


Fig. 41.

Single Stitch Advancement. (Beard.) Suture placed and ready to tighten. Dotted portion embedded in sclera. Single broken line shows insertion from which tendon has been divided.

the stitch is placed. A fine, perfectly sharp, half-curved needle is threaded on each end of a No. 1 braided black silk suture. This has been boiled in equal parts of paraffin and vaselin. Both needles are passed through the tendon from the conjunctival to the scleral surface, as shown in Fig. 41, the distance back from the end of the tendon being determined by the extent of the advancement desired. The upper needle is carried beneath the conjunctiva, above the cornea, for some distance; and then made to enter the firm scleral tissue, through which it passes to a point 4 or 5 mm. above the limbus at or beyond the vertical meridian, where it is made to emerge. The lower needle is carried below the cornea in a similar way. During the procedure the eye may be fixed by grasping the tendon firmly at its insertion.

The part of the suture crossing the tendon has been left loose up to this time. The upper end of the suture is then passed under it, and the two ends brought together. Both loops of the suture are carefully

held out of the way while the tendon is raised and divided as far from the insertion as the case may require. The stump thus left is cut off even with the sclera. The loop of suture across the tendon is drawn tight, the assistant draws the eye into proper position, and the operator ties the suture. It may be tied in a bow-knot and readjusted after 24 hours; or tied with a fixed knot at once. Ritchie (*Jour. Oph. Otol. and Laryngol.,* Vol. XVII, p. 155) has modified this operation by carrying back the ends from above and below the cornea beneath the conjunctiva to near the tendon advanced, where they are tied.

Howe (*The Muscles of the Eye,* Vol. II, p. 351) has done an operation resembling this in the main, but instead of entering the scleral tissue for anchorage he causes the upper suture to include the nearer margin of the superior rectus tendon near the insertion; and the lower anchorage similarly to include a portion of the inferior rectus tendon. The suture is allowed to remain 6 to 9 days, the eye being dressed and the dressing changed every 48 hours. For the first two days both eyes should be bandaged and absolute rest in bed insisted on. Beard (*Ophthalmic Surgery,* p. 179) accompanies the advancement by a partial tenotomy of the opposing muscle. Where the suture is first tied in a bow-knot the ends should be made fast near the canthus by a bit of adhesive plaster.

Advancement with splitting of the tendon. This operation was described by Valude (*Annales d'Oculistique,* Vol. 116, p. 112) in 1896. He exposes the tendon by a vertical incision and introduces two sutures; one at the junction of the upper end and second quarter of the tendon; the other at the junction of the lower and third quarter. The tendon is then divided at its insertion, and split horizontally 6 or 8 mm. back from the insertion. One-half of the tendon is then sutured above, the other half below the cornea, as shown in Fig 42. Terson has described (*Presse Méd.,* July 20, 1910) a similar advancement of the split tendon, but with a third suture passing directly from the middle of the tendon toward the cornea. Gouin (*Ann. d'Oculist.,* Vol. 145, p. 340) uses a tangential middle stitch. See also the folding operations of Colburn and Magnani.

Special forms of suture for muscular advancement. These constitute the most important features of a large number of modifications of muscular advancement. Argyll-Robertson (*Brit. Med. Jour.,* 1891, Vol. II, p. 471), after dividing and isolating the tendon, in much the same manner as Williams and Beard, used a double-armed waxed silk suture, one end of which was passed in and out through the tendon or muscle parallel to the corneal margin, and a sufficient distance back from the insertion to give the desired advancement. The needle was

then passed beneath the conjunctiva, around the cornea, well beyond its opposite margin. The second needle was then similarly passed in and out through the conjunctiva around the other half of the cornea to emerge near the first needle. See Fig. 43. After excision of so much of the tendon as it was desirable to remove, the parts were brought into apposition and the suture tied. This suture was allowed

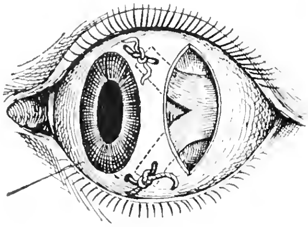


Fig. 42.
Advancement with Splitting of Tendon. (Valude.) Showing tendon sutured in new position, conjunctival wound not yet closed.

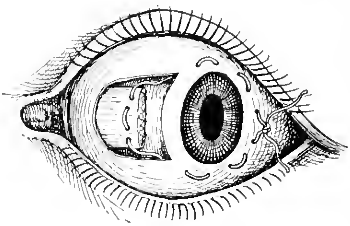


Fig. 43.
Advancement with Suture Carried around the cornea. (Argyll-Robertson.)

to remain 4 or 5 days. This carrying of the suture around the cornea has also been tried by Cogan (*Ophthalmic Record,* 1906, p. 357). Howe (*The Muscles of the Eye*, Vol. II, p. 355), also, after anchoring the stitches by catching his sutures through a small loop near the center of the tendons of the superior rectus and the inferior rectus,

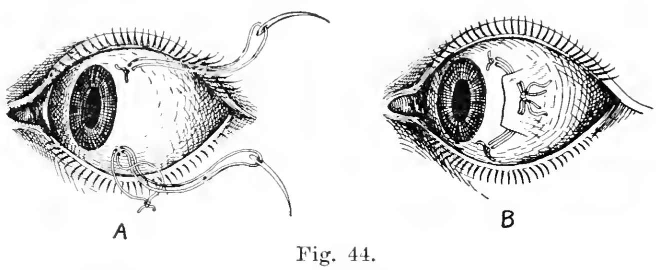


Fig. 44.
Advancement with Two Sutures. (Black.) A Shows the Upper Suture anchored in the sclera, the lower suture passed through the sclera and through the loop, but not yet drawn tight. B shows the two sutures passed through the flap, drawn up and tied.

carried these ends around to the external rectus, which was also caught in the suture that was tied over it.

Melville Black (*Arch. of Ophth.*, Vol. XXIV, p. 375) suggested the following: Two fine curved needles are threaded with No. 3 silk, and the two ends of each suture tied together (or needle may be double threaded), so as to make a closed loop. The sutures are made fast

to the eyeball by passing each needle through the conjunctiva, and deep enough to get a "good bite" into the sclera, close to the cornea, as shown in Fig. 44.

After passing through the ocular tissue the needle is slipped through the loop and the latter drawn tight. This gives a firm anchorage to the stitch. The tendon is then isolated and raised on the strabismus hook, and each suture is passed through the tendon from the scleral to the conjunctival surface near the corresponding margin of the tendon. The tendon is then cut off at the proper distance in front of the sutures, and the stump cleanly dissected from the insertion. The two double ligatures are then tied over the tendon, as shown in Fig. 44.

It is of historical interest to note that Bajardi (Turin, 1896), among various modifications of the sutures, proposed one in which they should pass through the lids, and be tied over a shot or bead upon the skin surface. Swanzy (*Handbook of Diseases of the Eye and Their Treatment.* Chapter XVIII) and de Schweinitz (*Diseases of the Eye.* Sixth Ed., p. 869) use two sutures each enclosing one-half the breadth of the tendon. These sutures are brought forward to emerge from the conjunctiva near the vertical meridian above and below the cornea. Sauvineau (*L'Ophtalmologie Provinciale.* March, 1908) has used a similar stitch for the Motais advancement.

The arrangement of the sutures adopted by Wootton (*Arch. of Ophth.,* Vol. XXX, p. 229) is shown in Fig. 45, which represents the sutures entirely placed, ready for closure of the wound. Wootton isolates the tendon and permits the conjunctiva to retract. Then he introduces the muscle end of the suture, passing the needle first through the conjunctiva about 1 mm. from the cut edge. The tendon is then cut close to the points penetrated by the suture; after which the corneal end of each suture is introduced, no conjunctiva being sacrificed. Elschnig (*Ophth. Record,* Vol. XXI, p. 655) uses three sutures placed in much the same manner but having something of a cross hold on the fibres of the tendon, and a deep scleral anchorage, the middle one at the corneal margin, the upper and lower at the insertions of the superior and inferior recti. Ohm (*Klin. Monatsb. f. Augenh.,* May-June, 1911, p. 714) passes sutures through the margins of the muscle back of the tendon and through the insertions of the superior and inferior recti.

Thomson (*Ophth. Rec.,* March, 1905) has modified this operation by introducing the threads only through the margins of the tendon before dividing the tendon 1 mm. in front of the stitches. The muscle is then drawn forward by traction on these stitches and the middle suture introduced, first into the center of the tendon and then superficially

in the sclera at the corneal margin. The anterior or limbus ends of the lateral sutures are then placed and the sutures tied, the middle one first. After the tendon has thus been advanced the free ends of the sutures are used to suture the conjunctiva.

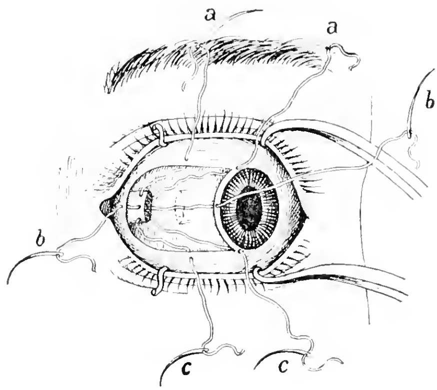


Fig. 45.

Advancement by Wootton's Method. Stitches Placed and Tendon Cut Off; a, upper, b, middle, and c, lower stitch.

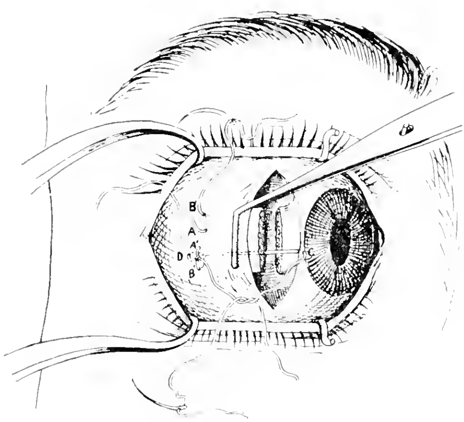


Fig. 46.

Advancement Sutures as Placed by Worth. A B Shows Suture Introduced first time through tendon. A′ B′ D C suture passed second time through tendon and through limbus ready to tie.

On account of the tendency of finer threads to cut through the tissues, Worth (*Ophth. Rec.*, Vol. XXIII, p. 616) employs white silk, boiled to sterilize it, and anointed with sterile vaseline. The conjunctival incision is made convex to the cornea to favor retraction of the

tissues. The advancement forceps are introduced, and the tendon and retracted conjunctiva clamped together. (See Fig. 46.) The needle of one suture is then passed from conjunctival to scleral surface at A. It is brought out through the same tissues at B, so as to include one-fourth the width of the tendon. In the same way the second stitch is carried in at A′ and brought out at B′. The suture is then given a "half-hitch," forming a loop A′B′C, which includes one-fourth of the width of the tendon. The end of the suture carrying the needle is then passed through the tissues from the conjunctival to the scleral surface at D; and carried forward beneath the tendon to the limbus, where it is passed through the tough "circumcorneal fibrous

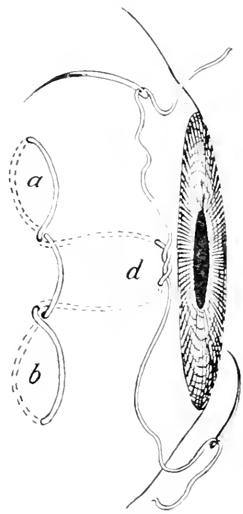


Fig. 47.

Advancement Stitch of Stevenson. Loops a and b Include the Tendon. Suture ready to tie at a. Buried portions of suture shown in broken lines.

tissue" and is brought out at G. In the same way the first suture entered at A is tied to include one-fourth of the tendon and the needle passed beneath and through the circumcorneal tissue at G.

The portion of the tendon and conjunctiva grasped by the forceps is then excised. The sutures are tied in loose knot at H, and the tendon drawn forward. When the parts have been properly brought into apposition and redundant tissue removed the sutures are tightened. The patient, if a young child, is kept as still as possible in bed with both eyes bandaged for ten days. Woodruff (*Ill. Med. Jour.*, 1912, p. 577) for divergent squint following tenotomy for convergent strabismus uses the Worth sutures, but inserts them in the sclera at the site of the original insertion of the tendon and not at the limbus.

The stitch devised by Stevenson (*Sec. on Ophth., Amer. Med. Assoc.,* 1905, p. 174) is intended, like that of Worth, to catch the tendon in a cross loop; but to accomplish it by a single stitch. A black braided silk suture, No. 8, is threaded to a needle near each end. After a primary incision the conjunctiva and capsule are pushed well back, and clamped with the tendon in the advancement forceps. The tendon is divided. One of the needles is passed from the conjunctival surface through capsule and tendon at the junction of the upper and middle thirds of the latter; and then passed from the scleral surface outward through the same structures at the upper margin of the tendon. It is again entered at the first point of entrance forming to loop a. See Fig. 47.

The needle is then carried beneath the conjunctiva almost to the

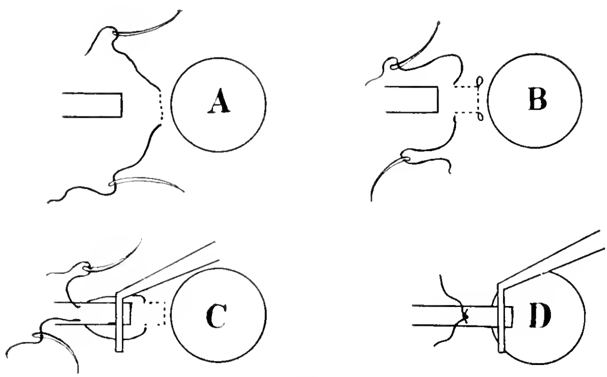


Fig. 48.
Advancement Stitch of Verhoeff Showing Different Stages. The Dotted Lines indicate the part buried in the sclera.

edge of the cornea where it is passed through scleral tissue. The needle at the other end of the suture is similarly used entering at the junction of the lower and middle third and forming the loop b. When completely placed the suture consists of two loops, a and b, connected by a central cross piece lying on the conjunctiva. The parts are brought into proper position, the suture tightened and tied at d, between the two points of scleral anchorage.

The simple stitch suggested by Verhoeff (*Ophth. Record,* 1901, p. 514) is illustrated in Fig. 48. The tendon is exposed through a vertical incision 3.5 mm. from the cornea, raised on a strabismus hook and isolated. It is then seized with the advancement forceps near the insertion. A double armed silk suture is used. It is first introduced into the sclera for 2.5 mm. as shown in A, one-half to one mm. from the corneal margin. Then each needle is introduced at the point of

exit of the suture, and carried horizontally 2.5 mm. towards the insertion of the tendon as shown in B. The tendon is then divided at its insertion and the two needles passed through it sufficiently far back, C. The tendon is then brought forward with the forceps, the eyeball rotated into position, and the suture tightened, D. A sufficient portion of the tendon grasped in the forceps is excised and the conjunctiva brought together by two superficial sutures.

Lee (*Ophthalmoscope*, Vol. VIII, p. 263), after exposing the tendon and clamping it with conjunctiva and capsule with the advancement forceps, divides it at its insertion. He then takes his suture of "not

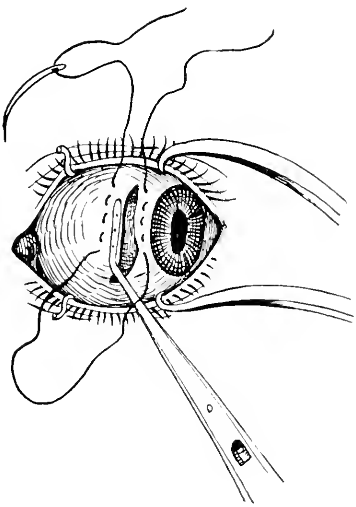


Fig. 49.
Advancement Stitch of Lee. The broken lines represent the suture running in and out of the tissues.

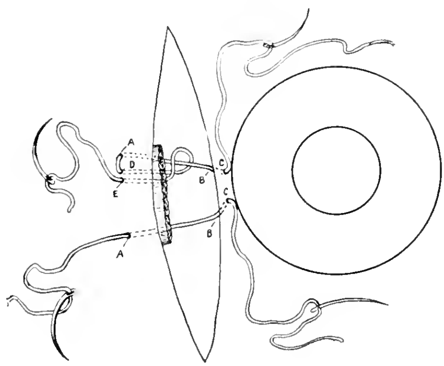


Fig. 50.
Advancement Stitch of Cogan. Both ends of the upper suture have been introduced so that it is ready to tie. Only the first needle of the lower suture has been passed.

too fine silk," which has been boiled in wax, and passes it through the conjunctiva and sub-conjunctival tissues near the cornea, making a running stitch which begins a little higher than the upper, and ends a little lower than the lower, margin of the tendon. The needle is then passed through conjunctiva and tendon in the same kind of stitch beginning below as shown in Fig. 49. The end of the tendon with the clamped tissues is cut off, and the stitch tightened.

The suture used by Oliver (*Ophthalmology*, Jan., 1906, p. 219) is double-armed. It is first carried beneath the isolated tendon or muscle. One needle is passed from the scleral surface out at the junction of the lower and middle thirds. The other is made to emerge at the junction of the middle and upper thirds. The tendon thus secured is freed

from the sclera. Each needle is then carried beneath the conjunctiva and into the anterior layer of the sclera 1 or 2 mm. from the limbus. The needles are then carried beneath the conjunctiva and brought out at points corresponding with the underlying sclero-conjunctival stitches.

In 1864 H. D. Noyes (*Amer. Med. Times*, Vol. I, p. 244) had used a somewhat similar stitch by which he says "the conjunctiva is drawn up over the cornea like the mouth of a purse, and the muscle is pulled forward." But in his later writings he does not refer to this method.

An elaborate stitch devised by Cogan is illustrated in Fig. 50. One needle of a double-armed suture is first entered at A and passed from the conjunctival surface through capsule and muscle, carried forward to B, where it enters the sclera, and brought out at C. The other needle of the same suture is entered at D, passing from conjunctival to scleral surface, and is carried out under, and back over, the portion of the same suture running from A to B. It is then brought through from the scleral to the conjunctival surface at E. The second suture is similarly introduced near the other edge of the tendon.

Advancement with folding of the tendon. Although various writers have proposed operations in which the tendon was folded without any cutting thereof, the excision of the fold thus made is usually mentioned as a trifling modification of the operation; and it is often recommended as being followed by less swelling of the parts and more rapid return to normal. No sharp distinction can be made between operations of this class and the forms of advancement already described. A distinction is often made between folding the tendon forward to the corneal margin, "folding forward," and making the fold entirely behind its insertion, "tendon tucking" or shortening. Yet after doing the latter operation some operators prefer to stitch the loop so formed to the sclera in advance of the insertion. We will here consider, first, operations in which the fold in the tendon is made without special apparatus.

Tendon folding by suture. The oldest of these operations is the so-called capsular advancement of de Wecker (*Annales d'Oculist.*, Vol. 70, p. 225). An incision is made over its insertion, and the tendon isolated and raised with de Wecker's double advancement hook. A suture threaded to three needles is then taken, the central needle is passed through the center of the tendon from the scleral surface outward; and each of the other needles is passed beneath the conjunctiva to a point in the vertical meridian of the eyeball 3 or 4 mm. back from the corneal margin as shown in Fig. 51. The thread is then cut in the middle, making two sutures. These two sutures can be tied separately in the ordinary way, the two ends of the lower suture together. But

de Wecker chose to tie the corneal end of the upper suture to the muscle end of the lower suture; and the muscle end of the upper suture to the corneal end of the lower suture. In this way he made in effect a single crossed suture, making it impossible to draw the lower part any more or any less tense than the upper. He hoped thus to avoid drawing the tendon of a lateral muscle either upward or downward and thus changing its plane of action. Subsequently de Wecker practiced his capsular advancement with division of the tendon in some cases, and also employed a stitch resembling that suggested by Savage.

What he calls a tendino-capsular advancement was described by Knapp (*Tr. Amer. Ophth. Soc.*, Vol. IV, p. 345) in 1886. In general character it is essentially the operation of de Wecker. But the sutures

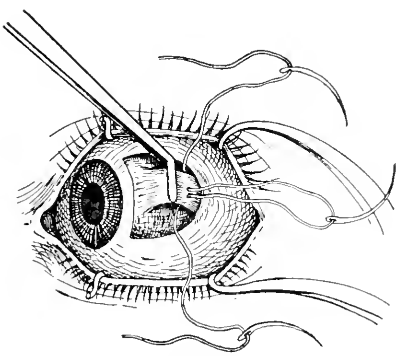


Fig. 51.

Advancement by the Method of de Wecker showing introduction of sutures.

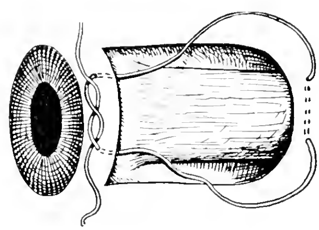


Fig. 52.

Folding of Tendon as Done by Lagleyze.

employed are placed as in the advancement done by Critchett. Knapp (*System of Diseases of the Eye.* Norris and Oliver, Vol. III, p. 877) says: "The operation in fact is the same as Critchett's, without excision of a piece of tendon."

The operation of muscle shortening described by Lagleyze (*Arch. d'Ophth.*, Vol. XXII, p. 668) in 1891 is done as follows: The conjunctival incision is made concave to the corneal margin, in advance of the tendon insertion, and a flap of conjunctiva covering the insertion is excised. The tendon is exposed and isolated on two strabismus hooks. A double-armed suture is introduced by passing both needles from the scleral surface outward through the tendon or muscle and conjunctiva sufficiently far back from the insertion; one needle being passed 1 mm. from each margin of the tendon or muscle. The needles are then entered beneath the conjunctival flap adjoining the cornea, and super-

ficially into the sclera, and brought out at the corneal margin, as shown in Fig. 52. The tightening of the suture folds the tendon forward almost to the corneal limbus. The suture is allowed to remain ten days to secure firm union.

An operation for shortening an ocular muscle by folding the tendon on itself by simple suture was described by Savage (*Ophth. Record,* March, 1893) in 1893. A vertical incision is made in the conjunctiva 3 mm. posterior to the insertion of the tendon, and a little longer than the tendon is wide. From the lower extremity of this, a horizontal incision 6 mm. long is made near to the lower border of the muscle. The triangular flap is dissected up and held aside. A puncture is made in the capsule at the lower border of the tendon, a strabismus hook introduced beneath the tendon and a second puncture that permits the tip of the hook to appear above the upper margin of the tendon. A suture double-armed is introduced thus: The tendon being raised by the strabismus hook, and the muscle by forceps, each needle is passed through capsule and muscle from the outer to the scleral surface; as far back as it is desired to include the tendon or muscle in the fold. One needle is passed in the upper half, the other in the lower half of the tendon, so as to include fully one-fourth the width of the muscle between the punctures. Each needle is then passed through the insertion of the tendon from behind forwards, opposite the point at which it enters the muscle; and brought out through the conjunctiva directly over the insertion. The suture is then tightened and tied, bringing the included portions of the tendon (and muscle) into a loop. To the extent of the loop it shortens the distance between the origin and insertion of the muscle, without changing the position of the insertion. The loop is covered by the conjunctival flap and the stitch allowed to remain 4 to 6 days. The knuckle of the muscle thus formed is left to undergo absorption. A very similar operation was subsequently described by Brand (*Centralbl. f. p. Augenh.,* 1902, p. 208).

Woodruff (*Jour. Ophth. and Oto-Laryngol.,* Apr., 1910) uses in tendon-tucking a stitch like that devised by Worth, except that it does not include the conjunctiva, which is dissected from the deeper parts as far back as possible, held aside for the operation, and afterward closed by separate suture.

Suffa (*Arch. of Ophth.*, Vol. 38, p. 254) has folded the tendon by the following somewhat elaborate stitch: After exposing and isolating the tendon a double-armed suture is laid across the tendon at A, Fig. 53, sufficiently far back from the insertion to give the required amount of shortening. The needle attached to the upper end of the suture is introduced beneath the tendon, which is made to pierce the scleral sur-

face at B, at the junction of the upper and second quarters of the width of the tendon, in front of the suture A. It is then carried over the suture C, where the needle again pierces the tendon, from the conjunctival to the scleral surface, and is carried beneath the tendon to its insertion, where it pierces, emerging at D. The lower end of the suture is similarly carried through at the junction of the lower and third quarters of the tendon, back, through and forward to the insertion. The tendon is folded by tightening the sutures. The conjunctival opening is closed by a superficial suture on either side, being allowed to gape over the knot in the tendon suture.

Ziegler (*Tr. Amer. Ophth. Soc.*, Vol. XIII, p. 622) does a single stitch capsulo-muscular advancement as follows: a 10 mm. vertical incision is made 4 mm. from the limbus and the tendon and muscle raised on two hooks. A double-armed suture is introduced, as shown

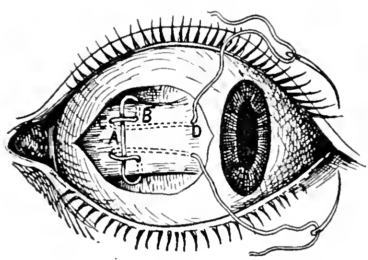


Fig. 53.
Stitch for Folding Tendon, Proposed by Suffa. Both ends introduced.

in Fig. 54. Each end of the suture is passed through firm scleral tissue near the limbus, and brought out so that the single knot is tied upon the surface of the conjunctiva. The tendon is not divided, but a V-shaped piece is excised from each margin with a special punch.

Bourgeois (*Arch. d'Ophtalmol.*, 1906, p. 356) after exposing and isolating the tendon introduces sutures, scrapes the surfaces that are to be folded together, and raises the loop on a spatula 4 or 5 mm. broad until it is drawn forward by the sutures. Worton (*Ophthalmoscope*, Vol. XII, p. 326) folds the tendon over a flat graduated guide, fastens the loop with three sutures, and with the free ends of these sutures fastens it down to the sclera at the corneal margin. He claims thus to have secured 12 mm. of shortening of the muscle, correcting 25 degrees of squint.

Stevens (*New York Med. Jour.*, Mar., 1889) excised a triangle of the tendon, its base at the insertion, its apex in the median line of the tendon, sufficiently far back from the insertion. The cut edges of the

tendon are then brought forward by sutures; the central portion of the tendon being most advanced or shortened, and the margins remaining undisturbed.

On account of the thickening caused by the loop of tendon formed by various folding operations, which he has practiced since 1886, Colburn (*Ophth. Rec.*, 1902, p. 197) prefers a combination of section and folding of the tendon. He opens the conjunctiva anterior to the insertion and dissects it backward, making a tongue-shaped flap. A central partial tenotomy is then made, leaving a narrow band of fibres

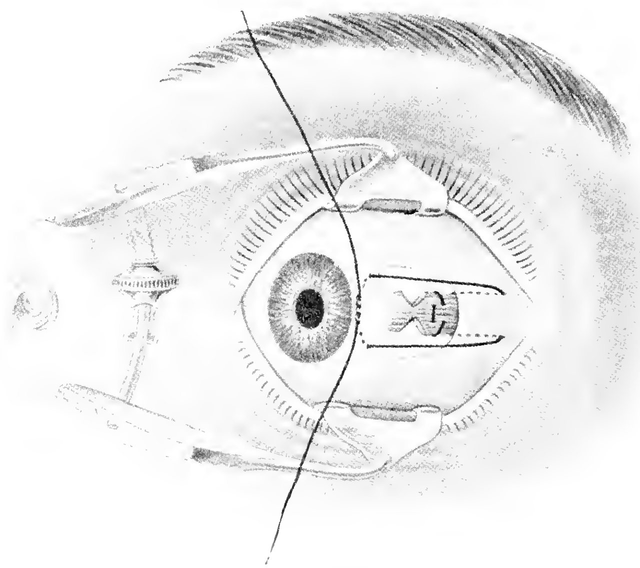


Fig. 54.
Both Needles have been Carried Forward, Passed Firmly into Sclera Near Limbus, and Ends of Suture Tied.

on each side. The end of the tendon then takes the shape of K K, in Fig. 56. The tendon is split at the center along H I, as far as it is desired to shorten it. A suture is passed through the center of the tendon entering near I from the conjunctival to the scleral surface, carried beneath the tendon from the site of its insertion beyond H, made to enter the sclera, and brought out near the corneal margin. Two additional sutures, L M and N O, are introduced in the two halves of the split tendon. The central stitch is tightened first, then the others.

An ingenious method of folding the tendon after splitting it is described by Magnani (*Annali di Ottalmologia*, XXXVII, 1908). An

incision slightly concave toward the cornea is made in the conjunctiva a little in front of, and somewhat longer than, the insertion of the tendon. The tendon is then exposed, isolated for a sufficient distance back of the insertion, and split longitudinally in the middle, without dividing the insertion. Five sutures are introduced as shown in Fig.

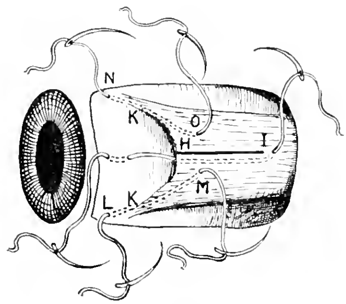


Fig. 56.
Advancement by Folding after Partial tenotomy and splitting of the tendon. (Colburn.)

57. Two of these, A and B, enclose each one-half of the split tendon in its loop and are then carried beneath the conjunctiva, the free ends emerging near the vertical meridian of the eyeball. Next to each of these comes a suture, C and D, which penetrates the corresponding half of the tendon near its insertion, and also sufficiently far back to

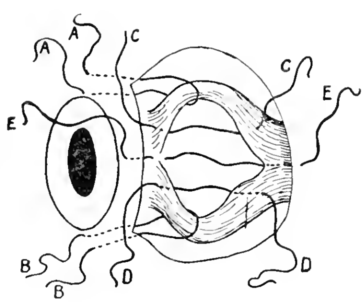
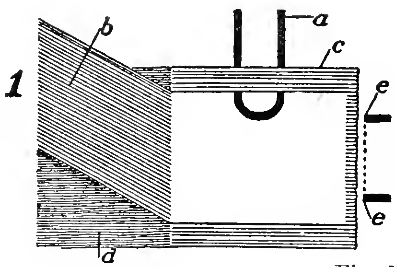


Fig. 57.
Folding Forward of the Split Tendon. (Magnani.) The Sutures are Introduced ready to tighten, beginning with E.

aid in the folding of the tissues. The fifth suture, E, is placed in the median line of the tendon, piercing it back of the slit, and taking a firm hold on tissue at the seat of the tendon insertion before it is brought out through the conjunctiva near the limbus. The tightening of these threads produces a folding of the split portions of the tendon,

with drawing forward and shortening of the muscle as a whole. The threads are removed on the sixth day.

Trousseau (*Annales d'Oculistique*, 1903, p. 17) under the name "capsular ligature," has described a very simple, but he claims, effective form of advancement. Without opening the conjunctiva the tendon is grasped through the conjunctiva and raised from the eyeball with forceps. A half-curved needle is then introduced near the sclerocorneal junction, and through the insertion of the tendon. The needle



(*a*) Cat-gut strand.
(*b*) Reflected central portion of tendon.
(*c*) Marginal strip of tendon.
(*d*) Muscular portion.
(*e*) Suture passing through scleral insertion which will hold central section of tendon.

Fig. 58.

O'Connor's Operation for Tendon Shortening. Introducing Loop Under Upper margin into window cut in tendon.

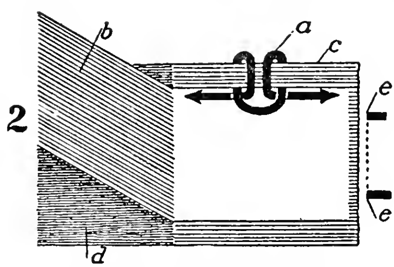


Fig. 59.

Cat-gut Looped Around Upper Border of tendon. Ends must be separated and not crossed.

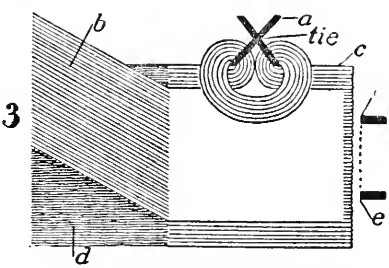


Fig. 60.

Cat-gut Drawn Upon and Ready to tie, making double loop in the strand of tendon.

Letters the Same as in Fig. 58. Numbers on Left Indicate Succession of Stages in operation.

passes beneath the ocular surface of the tendon a sufficient distance, and the point is brought out through the tendon and conjunctiva. The suture is then drawn upon sufficiently and tied. The suture is allowed to remain 6 to 12 days, being removed earlier if the effect seems likely to be excessive. Removal of the thread on the second or third day was followed by diminution of the effect to the extent of 5 to 8 degrees. Trousseau has used this operation like other forms of advancement. It is one that might be used to supplement a tenotomy producing insufficient effect.

O'Connor (*Jour. Amer. Med. Assn.*, March 2, 1912) described a most original means of muscle shortening. He split the tendon into four strands and formed around each a loop of cat-gut. Then by traction on the gut he straightened it and transferred the loop to the strands of tendon. Later (*Ophth. Rec.*, Vol. XXIII, p. 595) he modified his operation as follows: The tendon is fully exposed, and a strand 1.5 mm. wide is split along each edge. The remaining central part of the tendon may be divided near its insertion. On each marginal strand a loop of cat-gut is formed as shown in Fig. 58 and Fig. 59. Traction on the gut transfers the loop to the strand of tendon, as shown in Fig. 60. The shortening thus caused is more than twice the diameter of the gut. The gut is then tied, but not so tightly as to constrict the tendon. When both edges of the tendon have thus been shortened the central portion may be stitched to the sclera near the limbus or upon the insertion of the tendon. No tension will come upon the sutures until the cat-gut has been absorbed. Twenty-day tanned, non-iodized gut is employed. Chromicized gut caused too severe a reaction. O'Connor (*Tr. Sec. on Ophth. A. M. A.*, 1916, p. 236) points out that this operation may be modified by shortening only one margin or shortening one more than the other, so as to correct torsion.

Folding the tendon with special instruments. Tendon folding with the triple hook was first described by Maxwell (*Brit. Med. Jour.*, 1896, Vol. II, p. 819). After exposure the tendon is taken up on a strabismus hook, and its side attachments divided by scissors, cutting backward along each side of the tendon. An instrument having two parallel fixed hooks, and a central movable hook to slide between them, is placed so that the central hook takes up the tendon. The central hook has been protruded to do this. It is then drawn in, its motion being controlled by a screw and indicated on a millimeter scale. When a sufficient loop of the tendon has been drawn between the two fixed hooks, a suture with a needle at each end is passed through the doubled tendon from behind forwards as close above the fixed hooks as possible. The hooks are then removed, the suture tightened with a temporary knot, and the effect tested. If this is too great or insufficient, another suture may be introduced and the first removed. When the right amount of shortening is secured a permanent knot is tied. A loop of tendon now projects from the wound. A double-armed suture is passed through this loop, and the needles carried beneath the conjunctiva sufficiently far back to draw the loop smooth and flat. The latter suture may be taken out in one or two days; but the first suture should be left for a week.

The form of hook described by Clark (*Trans. Sec. on Ophth., Amer. Med. Assoc.*, 1900, p. 164) is shown in Fig. 61. The central movable hook placed between two fixed hooks can be made to project, or can be drawn up by means of a milled screw and ratchet. The handle is detachable, so that in the absence of an assistant it may be removed, leaving the hooks as a clamp holding the tendon in position for introducing the sutures. Clark prefers to include as much of the capsule as possible in the fold. Three stitches are used, the lateral sutures interlocking with the central one. Clark at first suggested excision of the loop, but later stitched it down anterior to the tendon insertion.

Bruns (*Ophth. Rec.*, 1904, p. 267) modified the instrument of Clark by giving the central movable hook a longer bearing in the milled screw collar. To secure the loop he uses a double suture which transfixes the

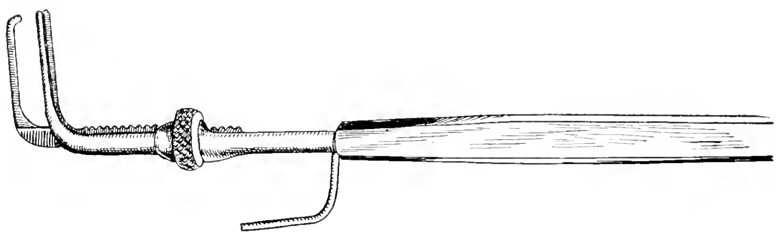


Fig. 61.
Clark's Double Hook for Advancement by Folding the Tendon.

center of the tendon. The needle being cut off, each half of the suture is tied around the corresponding half of the tendon. Bruns also had a hole drilled in the tip of the movable hook. After securing the tendon a ligature is threaded through this hole. As the hook is withdrawn it carries the thread through the loop. This is armed with a needle at each end, and these needles are carried beneath the conjunctiva, one towards the upper, the other towards the lower corneal margin. They are brought out at the limbus near the vertical diameter. One end is then carried back to the posterior flap of the conjunctiva and passed through it. The tying of the two ends together, and the tightening of the loop of the suture, spreads the tendon flat upon the sclera towards the cornea, and brings forward the posterior flap of the conjunctiva. This "guy suture" becomes slack and should be removed in a week. The sutures in the tendon can be left for months or permanently.

More recently, Stroschein (*Klin. Monatsbl. f. Augenh.*, Jan., 1910, p. 43) has described another form of triple strabismus hook, the central hook movable by a sliding button.

Tendon tuckers. A different method and instrument for folding the tendon were devised by Greene (*Ophth. Rec.*, 1899, p. 462). These are illustrated in Fig. 62. The instrument consists of forceps handles with one straight and one angular blade, each carrying a tip or tine perpendicular to its general direction. After exposure and isolation of the tendon, the tip of the straight blade is introduced beneath it while the tip of the angular blade rests upon the insertion. Pressing the blades together causes the one tip to pass the other, forming a fold, the extent of which can be fixed by the set screw. When, by this folding, the eye is brought into proper position, the fold is made permanent

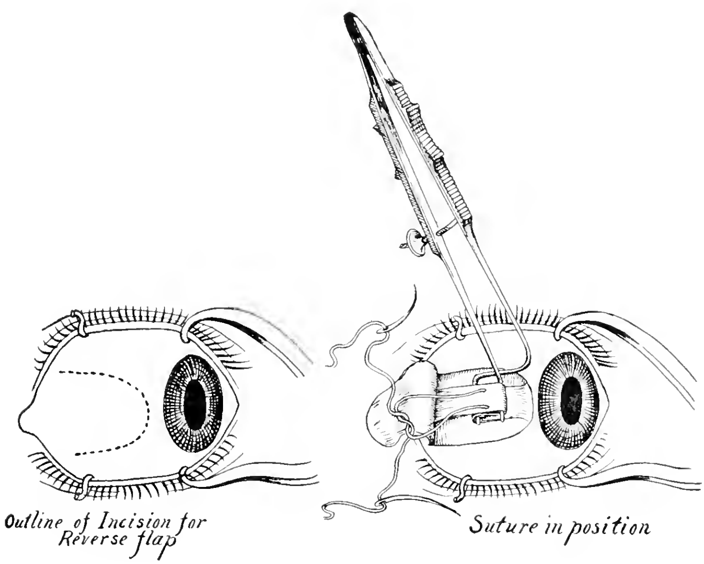


Fig. 62.
Greene's Instrument and Operation for Folding the Tendon.

by passing each needle of a double-armed suture through the three thicknesses of the folded tendon, from the scleral side outward, and tightening the ligature with a permanent knot.

A different instrument for the purpose was devised by Todd (*Ophth. Rec.*, 1902, p. 73, and 1914, p. 628). The instrument consists essentially of two prongs each hooked to prevent the tendon from sliding off, their position being controlled by a screw. After exposure and isolation of the tendon by dissecting up a conjunctival flap, one prong is introduced beneath the tendon, and by use of the screw the prongs are made to move past each other, causing a double folding of the tendon. When this folding is deemed sufficient to bring the eye into

proper position, two catgut sutures are introduced and tied. Then a silk suture, double-armed, is introduced. One end is carried through the conjunctival flap, as shown in Fig. 63. The other end is carried through the folded tendon just back of the catgut suture, and then forward under the conjunctiva, into firm scleral tissue, emerging above the cornea. The tendon tucker is then removed, and a corresponding suture introduced through the lower portion of the flap, tendon and loop, emerging below the cornea. The silk sutures are used to regulate the amount of effect produced. They may be left tied with a temporary knot until the next day, when a readjustment can be made and a permanent knot tied.

Harman (*Trans. Ophth. Soc. United Kingdom*, Vol. 32, p. 246) devised what he called "reefing forceps," one arm of which is

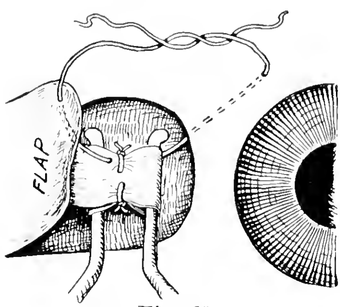


Fig. 63.

Todd's Operation for Tendon Tucking. Showing Loop of Tendon Held on prongs of instrument, cat-gut sutures introduced, and placing of regulating suture for upper edge of tendon.

arranged to slide on the other to any desired extent shown by a scale, and which can be set by a screw clamp. The protruded blade is placed on the end of the tendon, the other beneath the tendon, with the handle away from the cornea. The handle is then carried across the cornea folding the tendon, and the fold fixed with sutures. The anchor stitch, introduced at the beginning of the operation, is used to control the position of the eye while operating; and then tied over adhesive plaster near the canthus to keep the eye turned in the direction of the advanced muscle.

A very elaborate instrument for grasping the tendon and folding it has been suggested by Levinsohn (*Klin. Monatsbl. f. Augenh.*, Sept., 1909). It is shown in Fig. 64. The exposed tendon is grasped at two points, sufficiently far apart, by closing the short handles that operate the jaws of the instrument; and this hold on the tendon is retained by the spring catches. By bringing together the long handles the closed

jaws are made to pass each other, causing a folding of the tendon to any desired extent, when the instrument may be fixed by the toothed catch at the end of the long handle. In contrast with the above is the method of Vacher and Danis (*Clin. Ophth.*, Vol. XIX, p. 634). The tendon is grasped between the arms of fine forceps held at right angles to the direction of the tendon and tangent to the eyeball. Twisting the forceps rolls the tendon around them and brings the desired amount of shortening.

A *tendon clamp* for forming and retaining the fold in the tendon has been worked out by Briggs (*Tr. Amer. Acad. Ophth. and Oto-Laryngol.*, 1908, p. 212). He fixes the looped tissue by clamping it with a ring of silver wire. The special instruments required are shown in Fig. 65. They include a strabismus hook small enough to go through

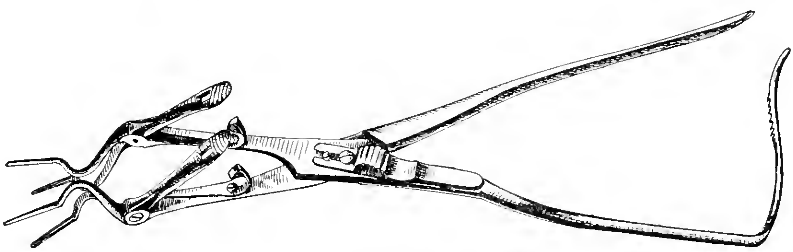


Fig. 64.
Reefing Forceps of Harman. Upper Closed, Lower Extended.

the ring, forceps for clamping the ring, rings of silver wire of appropriate size, and wire scissors for cutting the ring when the time comes to remove it. The ring of wire is an oval, with a major axis of 5 mm. and a minor axis 2 mm.

A small opening is made in the conjunctiva and capsule at one edge of the tendon to be folded, and 2 to 4 mm. behind its insertion, according to the amount of shortening intended. An ordinary strabismus hook is passed beneath the tendon, and held by an assistant. The ring is held in the clamp forceps over the structures to be looped, and the small strabismus hook passed through the ring is substituted for the one first used to raise the tendon. By the small hook the tendon with overlying conjunctiva and capsule is drawn up through the ring to the desired degree; and the jaws of the clamp forceps forcibly approximated, closing the ring tightly on the included tissues. If a great deviation is to be corrected, after drawing the tissues slightly through the ring the conjunctiva may be incised, and only the tendon shortened to the desired degree. If a large loop of tendon is thus included, the greater part of it should be cut off, leaving only enough to prevent

retraction of the cut ends. Within twenty-four hours the strangulated tissues become white and begin to atrophy. They should be excised on removal of the ring, at the end of ten or fourteen days. The ring is removed by cutting it with the special wire scissors at each end.

Shortening a muscle with section or resection. In the advancement operations that seek to bring the insertion of one of the recti muscles closer to the cornea the tendon is divided; and often part of the tendon, with or without other tissues, is excised. In shortening by folding the tendon, the loop formed by the operation may be cut away.

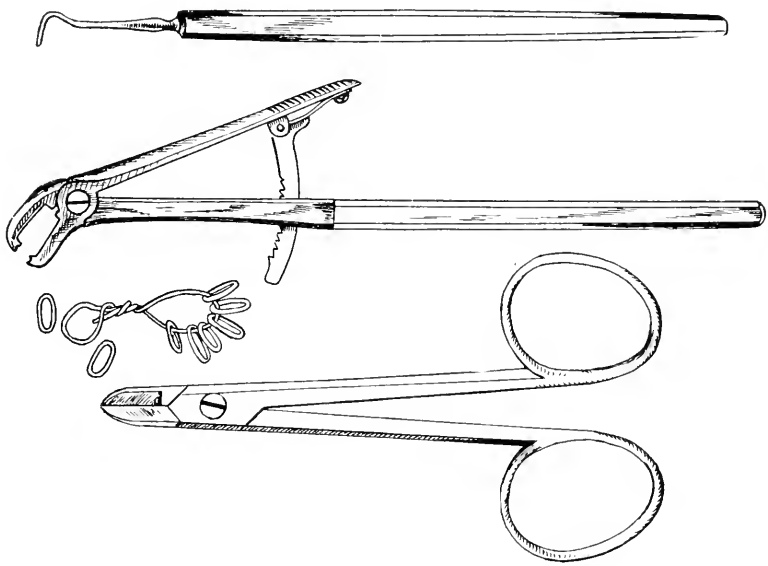


Fig. 65.

Briggs' Instruments for Tendon Shortening by Use of Silver Wire Clamp. Small strabismus hook to slip through wire ring, forceps for clamping ring, silver wire rings, special scissors for cutting silver wire.

We here consider operations in which the tendon is divided and lapped, or a portion excised, and the muscle reattached to the original seat of insertion. The first, and still one of the best, operations of this kind was proposed by J. F. Noyes (*Tr. Amer. Ophth. Soc.*, Vol. II, p. 273). Two years later substantially the same operation was published by Driver (*Klin. Monatsbl. f. Augenh.*, 1876, p. 133). See Fig. 66.

The conjunctiva is opened by a horizontal incision directly over the tendon, and long enough to expose a sufficient portion of it. The tendon is raised on the strabismus hook, seized by the advancement forceps; and divided far enough back of the insertion to allow the

muscle part of the tendon to be pulled beneath the stump and secured to it by sutures. The two surfaces of the tendon which are brought together should be freshened by a knife. Two stitches are used. One is introduced through the conjunctiva, and then from beneath through the overlapping portion of the tendon near each margin. Blanco (*Archivos de Oftalmol.*, Vol. XI, p. 57) places the muscular portion of the tendon behind the part attached to the insertion. Callan (*Tr. Amer. Ophth. Soc.*, Vol. XI, p. 668) has removed as much as 12 mm. from the external rectus, correcting thereby a convergence of 35 degrees.

In doing shortening by resection of the muscle. Reese (*N. Y. Med. Jour.*, Jan. 13, 1912) uses three sutures. The middle one of No. 9 silk, double-armed, is passed from scleral to conjunctival surface of the

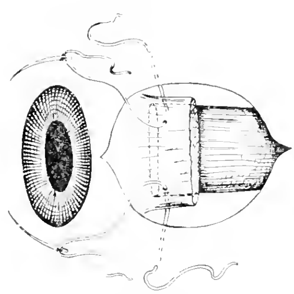
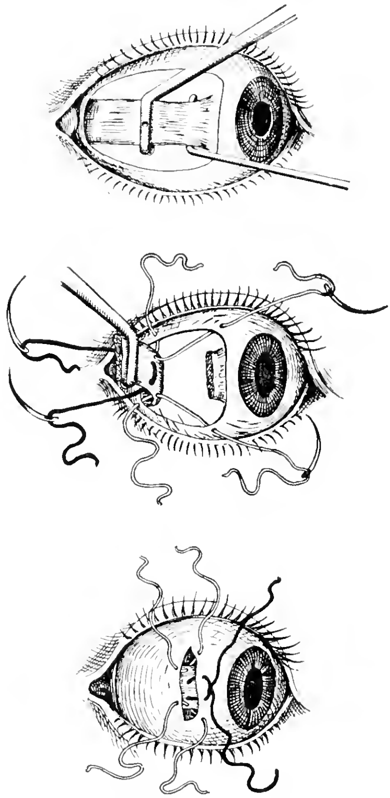


Fig. 66.
Advancement with Resection of the Tendon as Done by J. F. Noyes. The Broken line indicates end of muscle slipped under stump.

tendon, back of the forceps; one needle 1 mm. above and the other 1 mm. below the center of the tendon, the needles also piercing the edge of the more superficial tissue. The side sutures, of No. 5 silk, are passed through the edges of the tendon from the conjunctival surface toward the scleral, a little farther back than the central suture. The tendon is cut off at least two millimeters in front of the sutures; and all the sutures are made fast by passing the needles through the 2 mm. stump of tendon at the insertion. The central suture is left in ten days, the others 48 hours. The different steps of the operation are illustrated in Figs. 67, 68, 69.

Schweigger (*Arch. of Ophth.*, 1895, p. 8) after exposure of the tendon isolated it upon two strabismus hooks, and placed beneath it a spring gauge carrying two hooks. This gauge was set so that the two hooks were separated as many millimeters as the muscle was to be shortened, and held apart by the tension of the spiral spring. A needle attached to one suture was passed under the upper margin of

the muscle and pushed through below the middle of the muscle from the scleral to the conjunctival surface. The needle attached to the other suture was passed from the lower margin of the muscle and pushed through above the middle. These sutures were tied, each including more than one-half the width of the muscle, the central portion being included in both loops.



Figs. 67, 68, 69.

Advancement with Resection as Done by Reese. Above: Tendon Isolated Held by advancement forceps with groove to show middle of tendon. Middle: Sutures passed through tendon which is held back. Below: Sutures in place ready to tie.

The muscle being thus secured the tendon was divided near, but not directly at, its insertion; and a sufficient portion of it excised to permit neat apposition of the two cut ends. Each of the ligatures was then carried through the stump of the tendon at its insertion, made to dip into firm scleral tissue, and tied. The muscle at the point of ligation was thus brought forward to the scleral insertion.

Müller (*Klin. Monatsbl. f. Augenh.*, XXXI, p. 118) is careful to leave a 2 mm. stump of tendon at the insertion, and to amputate the muscle 2 mm. in front of the muscle sutures. He uses a third suture at the center of the tendon if there is much tension. These sutures are buried and left permanently.

General considerations regarding advancement operations. A large part of the difficulties regarding advancement operations arise from the character of the tissues dealt with. The conjunctiva and subconjunctival tissue (being extremely loose, easily dragged away from their normal position and readily cut by sutures) offer a poor anchorage for supporting sutures. That is the reason that many operators from the days of de Wecker have sought to include a great breadth of the conjunctiva in the sutures. This is why Argyll-Robertson, Howe, and Cogan have proposed to run the conjunctival sutures entirely around the cornea, making the whole of the firm attachment of the conjunctiva at the limbus available for support.

On the other hand the firm tissue of the sclera offers an ideal anchorage for sutures. The objection to its use is the risk of perforating the whole thickness of the sclera and opening a channel for infection to the interior of the eyeball. In attempting to place sutures in the sclera the needles used should be fine and sharp. The eyeball should be firmly held so that the needle will be passed just where it is intended. Even with care and in competent hands it is likely that complete perforation of the sclera is not very rare. Cogan, passing sutures in pigs' eyes, found the sclera perforated in half of them. H. D. Noyes (Textbook on *Diseases of the Eye*, p. 172) speaking of the needles making the deep anchorage at the sclero-corneal junction wrote, "I have seen the points sometimes appear in the anterior chamber, but this is, of course, too deep." Serious harm from such perforation, however, is barely mentioned in the literature of the subject, and must be very unusual. From the margin of the clear cornea it is 2 or 3 mm. back to the canal of Schlemm and the ciliary region. The sclerocorneal junction is the thickest part of the sclera. Although the introduction of sutures here is not free from risk, the danger is not great. Denig has even advocated the deep introduction of a suture in this region. (Graefe's *Arch. f. Ophthalmol.*, v. 88, p. 164). An aid to the exact placing of scleral stitches is the "fixation fork" of Batten (*Trans. Ophth. Soc. of United Kingdom*, v. 32, p. 131).

The tendons of the ocular muscles are thin and not adapted to offer any great resistance. To one who knows of them only through reading and work upon the hardened cadaver, it is a matter of surprise to find they are so thin and non-resistant especially in the direction

of their fibres. A suture can very readily cut out; and the muscle itself is less resistant than its tendon. Ewing (*Amer. Jour. of Ophth.*, v. 32, p. 129) employs eight different sutures. On this account it is important to have 2 or 3 mm., or more, of tendon projecting beyond any sutures that are placed in it to bear traction; and not to excise the tendon all the way back to the muscle. It is to guard against the friability of the tendon that crossed sutures like those used by Swanzy, and the elaborate stitches of Worth, Suffa, and others, have been devised. But the stitch which best meets the requirements, as pointed out by Harman (*Lancet*, May 25, 1912) is one, running across the fibres which holds the tissue of the tendon directly to that with which it is to be connected, as in the advancement operation preferred by the writer or that of Motais (*Bull. et Mem. de la Soc. francaise d'Opht.*, 1911, p. 198); or the stitching together of two layers of tendon in Savage's operation for folding, or Noyes' lapping of the tendon, or Ewing's "fixing sutures."

The difficulties of getting a firm hold for sutures at both ends make it important not to rely on such stitches to successfully resist any continuous pull. Advancement operations should in general accompany complete or almost complete tenotomy of the antagonist, which will for the time prevent any decided stress on the suture and the new formed attachments. If tenotomy be not done on the antagonist the keeping of both eyes closed for several days by bandages, and thus diminishing their active movements, is an inferior substitute. Advancement done alone is less efficient and less liable. It is possible that, because of greater certainty of result, folding or tucking operations will supersede some other forms of advancement.

In all cases of advancement where the purpose is simply to increase the influence of the muscle operated on, it is important that the *two edges of the muscle should be equally affected* by the operation. The placing and tightening of stitches must be done with this in mind. Although the single stitch operations are often supposed superior on this account, the same care must be observed with them in the placing of the stitch. In the folding or lapping of tendons one edge should be shortened just as much as the other. Here there is a superiority of instruments like the triple hook of Clark, in which the three hooks are always strictly parallel, over the instruments like those of Todd and Levinson, in which the prongs or jaws have more or less of a scissors movement, and only with a certain amount of folding can the prongs or jaws be parallel.

The anatomical changes actually produced by advancement operations are still uncertain, much less is known of them than about the

clinical results of such operations, and it is probable that our judgment with regard to their clinical applications would be improved by a better understanding of the anatomical changes produced by operation. It has been assumed that an advancement operation causes the tendon of insertion to form a new attachment to the eyeball at its anterior extremity; and to act upon this attachment as it did upon the original insertion. But the writer's experience in secondary operations agrees with that of others in showing that the advanced tendon does not become attached to the eyeball simply by its anterior extremity. The attachment may extend as far back as the original insertion of the muscle, and sometimes farther. This has been emphasized by Mueller (*Klin. Monatsbl. f. Augenh.*, Vol. XXXI, p. 118). Froelich (*Arch. of Ophth.*, 1905, p. 621) reports two cases in which this was proven to have occurred. Such reattachment of the tendons prevents any benefit from the attachment in the way of increasing the contact arc; although it does not necessarily cause such a diminution of the contact arc as tenotomy.

On the other hand instead of a too extensive insertion of the advanced tendon there is, after some forms of advancement, a risk that no firm attachment may be secured. The danger of this is slight if the antagonist has been rendered powerless by tenotomy. But where the antagonist retains its full power the danger is quite real, that after the removal of the mechanical support of the suture the new attachment will be so yielding or imperfect as to give way. This is the more apt to be the case in those forms of operation in which the advanced tendon is not stitched to the point at which a new attachment is to be formed; but is merely held in contact with that point by sutures which are anchored a considerable distance from the site of the new insertion.

Operations to enable one muscle to take up the functions of another. The recti muscles arise from practically a common origin. The peculiar action of each upon the eyeball depends on the relation of its insertion to the center of ocular rotation. If the insertion of the superior rectus muscle could be transferred to the normal position of the internus, and the muscle be at the same time freed from its intermediate attachments, it could perform the function commonly performed by the internus. If its insertion could be transferred to the normal insertion of the externus it would act like the externus. Any change in the insertion of one of the ocular muscles makes a corresponding change in its function. On this account a muscle wholly paralyzed can be partly replaced functionally by the transference of some other muscle. As each of the extrinsic ocular muscles takes part

in different ocular movements, it is quite possible, by slight changes in the positions of their insertions, to so change the relations of their different actions as to readjust them to altered requirements caused by loss of function in one or more of the other extrinsic muscles. Some such effect is produced by partial tenotomy which divides one edge of a rectus tendon while leaving the other unaffected. This has been explained under partial tenotomy.

Ocular palsies commonly conform to nerve distributions. Thus paralysis of the fourth cranial nerve produces paralysis of the superior oblique muscle; paralysis of the sixth nerve paralyzes the external rectus muscle; and paralysis of the third or oculomotor nerve paralyzes the other four extrinsic muscles; the superior and inferior recti, the internus and the inferior oblique. Each of these conditions is to some extent amenable to operative treatment.

Use of superior rectus to correct paresis of superior oblique. Contraction of the superior oblique causes intorsion, and helps to turn the eye out, or, when it is converged to turn it down. Paresis of this muscle causes extorsion, and weakness of movement outward and downward. Vertical diplopia, particularly with convergence and turning the eyes down, as for reading, is one of the most striking symptoms. The superior rectus opposes the superior oblique in regard to turning the eye down; and tenotomy of the rectus has been done to remedy weakness of the oblique. The result has been unsatisfactory because, although the superior rectus opposes the oblique as to turning down, and to a less extent as to turning the eye out, it is the principal aid of the oblique in producing intorsion or opposing extorsion. Hence, although tenotomy of the superior rectus helps matters as to turning the eye down or out, it makes things worse as regards the tendency to extorsion which is left without efficient opposition. Moreover, the weakening of the superior rectus leaves the upward movements of the eye dependent on the inferior oblique. This latter muscle is exerted more strongly and tends to produce still greater extorsion. This is further discussed in the section on choice of operation for paralytic strabismus.

The change in the insertion of the superior rectus that is required to meet a failure on the part of the superior oblique must be one that will diminish its tendency to turn the eye up or in, and will increase its power to produce intorsion, and give assistance in turning the eye out. Such a change is produced by transplanting the insertion of the superior rectus backward and outward. The indication would be met, to a slight extent, by a partial tenotomy of the superior rectus which should divide all but the extreme temporal fibres of the tendon, leav-

ing it to form a new attachment rather back and out from its original insertion. But in marked cases this is not sufficient, and a more radical transplantation must be performed, after careful calculation of the change of function desired.

Transplantation of the superior rectus. The eye and instruments are prepared as for an advancement operation, the lids widely separated, and the eye turned strongly down. An incision is made in the conjunctiva, starting 8 mm. above the cornea, and 2 mm. to the nasal side of the vertical meridian of the eyeball; and extending 10 mm. outward and a little backward from that point. This is carried down to the superior rectus tendon, which is bared of subconjunctival tissue, raised on a strabismus hook, and "stripped" back for 8 or 10 mm. by passing the hook back on each side of the tendon. The sclera is laid bare to the outer side of the tendon as far back and to the temporal side as may be necessary, with rather free division of the capsule in this direction. A fine needle threaded with silk, is then passed about 3 mm. back from the insertion at the junction of the middle and temporal thirds of the tendon, from the conjunctival to the scleral surface, and brought out beneath the temporal edge of the tendon. The point of the needle is then entered in the sclera as many mms. outward and backward from the point of introduction into the tendon as it is desired to displace the insertion, bearing in mind that each mm. represents about 5 degrees of change. The needle is carried in the sclera (deep enough to secure a firm hold, but not to perforate) for 3 or 4 mm., emerging that much nearer the nose than where it entered, and slightly nearer the cornea. The needle point is then introduced beneath the nasal edge of the tendon and made to emerge 3 mm. back from the insertion at the junction of the middle and nasal thirds of the tendon.

The suture thus placed is carefully drawn aside and guarded; and the tendon is divided at its insertion. Before the division the end of the tendon may be grasped (without excessive pressure) by advancement forceps. The tendon and eyeball are then to be brought into proper relative positions by forceps; and the suture drawn moderately tight, and tied so that the knot will lie in the conjunctival opening.

The after treatment includes closure with a light dressing for 2 or 3 days, and cleansing the eye once or twice daily. The suture can be removed after 6 or 8 days; or sooner if there is evidence of a decided excess of intorsion. The effect to be aimed at is an exact correction, or slight over-correction, of the motor deficiency. It is presupposed that the case is of such long standing as to have become quite stationary. The effect in the three cases thus far done by the

writer seems to be quite permanent, one of the cases now having been observed for 15 years (*Ophth. Review*, 1903, p. 61).

Change of line of insertion of a rectus tendon. For the correction of what he terms declinations of the eye, deviations of the meridians of the eye from their proper direction when the eye is in the primary position, Stevens (*Motor Apparatus of the Eyes.* Philadelphia, 1906,

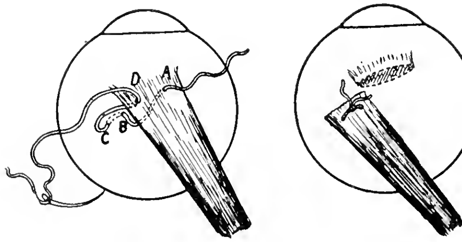


Fig. 70.

Transplantation of Superior Rectus for Paralysis of Superior Oblique. Introduction of suture before division of tendon; suture tied, the original insertion of tendon shown by broken line.

p. 340) does an operation that he calls extendo-contraction of the muscle. It may be done on either rectus muscle, but Stevens' preference is in this order, internal, superior, external and inferior. A small opening is made just over the upper border of the insertion, through which, with the points of the scissors, a pocket is formed beneath the conjunctiva, extending almost to the cornea, and half the width of the tendon. The tendon is divided at its insertion for a few

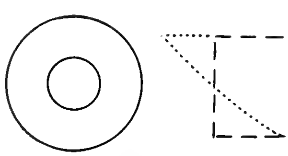


Fig. 71.

Change of Insertion of Tendon for the Operative Treatment of Declinations. (Stevens.) Broken lines show original position of tendon insertion. Dotted lines the new position.

mms. only. A delicate sharp hook is carried beneath it as far back as necessary, and made to catch the tendon below its upper border and draw it forward out of the conjunctival opening. A fine, double-armed suture is passed twice through the exposed part of the tendon; after which the remainder of the insertion is divided. The needles are then carried forward beneath the conjunctiva, with the aid of a director, to emerge, one near the upper margin of the cornea, the other

4 or 5 mm. from the first. This advances the upper margin of the tendon, while permitting the lower margin to slip back, as shown in Fig. 71.

Transplantation for paralysis of external rectus. Successful cases of this operation have been reported by Hummelsheim (*Archiv. für Augenheilkunde,* v. 62, p. 71, and v. 66, p. 57). His first patient, a girl of 12, with absolute congenital paralysis of the external rectus and inability to turn the eye beyond the median line, was given power to abduct the eye 30 degrees. The second, a woman of 47, with complete paralysis of the externus of 8 months' standing, and not benefited by other treatment, gained ability to turn the eye with monocular fixation outward 48 degrees, to preserve binocular distant vision to 16 degrees to the affected side and the binocular near vision to 30 degrees, and was relieved from very annoying diplopia.

An opening 12 mm. long was made over the tendon of the external rectus muscle. Through vertical incisions over their insertions the tendons of the superior and inferior recti were reached, raised and split in the middle about 12 mm. back, an incision 15 mm. long being made by the temporal margin. The temporal half of each tendon, grasped in tendon forceps, was separated from the eyeball at its insertion, and sutured to the insertion of the paralyzed muscle. The binocular bandage was used for 8 days, and the stitches removed on the eleventh day. No serious complications were encountered. Stuelp (*Klin. Monatsblaet. f. Augenh.,* Apr., 1912, p. 469) combined such a transplantation with tenotomy of the internus. A similar operation with good result is reported by Harris (*Oph. Rec.,* v. 25, p. 354).

Transplantation of the nasal halves of the superior and inferior recti to replace the internus was tried by Hummelsheim upon a monkey, with success. The internal muscle was rendered powerless by excising a segment of its tendon and muscular structure; and the adjoining halves of the superior and inferior muscles were connected with the insertion of the internus. The animal regained good power of converging the eye and of turning it toward the opposite side.

For paralysis of the externus Monzardo (*Ann. di Ottalmol.,* v. 39, p. 605) would attach the superior rectus to the tendon of the externus; and replace the superior by attaching to its insertion a part of the internal rectus.

Grafting of tendon of superior oblique. Transference of the tendon of the torn superior oblique to the external rectus has been reported by Dransart (*Révue Général d'Ophtalmologie,* 1907, p. 229), who also proposes the grafting of the tendon upon the upper edge of the externus or the nasal edge of the inferior rectus. He suggests an incision

through the skin at the upper inner angle of the orbit to expose the oblique at the pulley, and tunneling from there to the new point of attachment and drawing the tendon into the new position by a suture.

Transplantations for oculomotor paralysis. In paralysis of the oculo-motor nerve all the extrinsic muscles of the eyeball lose their power, except the external rectus and the superior oblique. These, being unopposed, turn the eye out, and the latter turns it somewhat down. Their action causes an unsightly deformity, although the extreme deviation, or the accompanying ptosis, usually prevents much annoyance from diplopia.

To prevent the extreme divergence the superior oblique can be taken up by the method described for tenotomy of that muscle, the tendon isolated, and divided far enough from the pulley toward the eyeball to furnish a sufficient length of tendon, the pulley then cut, the tendon drawn down and toward the eyeball, and the cut end of the tendon sutured to the tendon of the paralyzed internus near its insertion. This operation has been done by the writer upon the cadaver, but not on the living patient.

A still better position of the eye, and perhaps a little better movement, may be secured by subsequently splitting the external rectus for 15 mm. back from its insertion, and transplanting the upper portion to the temporal edge of the insertion of the superior rectus, and the lower portion to a corresponding relation with the inferior rectus. It is possible that in a young person a limited field of binocular fixation and stereoscopic vision could thus be re-established.

Passive motion was proposed by Michel (*Klin. Monatsbl. f. Augenh.*, Nov., 1877) as a means of increasing the power of partially paralyzed ocular muscles. But Snell (*Brit. Med. Jour.*, 1887, II, p. 661) has also used it to diminish the contraction of the internus in convergent strabismus. It is done under local anesthesia, but if done effectively is not without pain. The conjunctiva and tendon of the weakened muscle are firmly seized with strabismus forceps, close behind the insertion of the tendon; and the eyeball is forcibly rotated first in the direction of contraction of the muscle, then in the opposite direction, as far as possible with reasonable force. These movements are repeated rather slowly for about 2 minutes. This manipulation may be repeated daily if the irritation provoked does not demand a longer interval. Bull (*Tr. Amer. Ophth. Soc.*, Vol. IV, p. 450) reports eight cures in a series of twenty-one cases, while seven cases were partly relieved.

Stretching of tendon and connected structures was urged by Panas (*Arch. d'Ophtal.*, XVI, p. 1) as a remedy in ocular palsies and a valuable adjunct to tenotomy. After introduction of the strabismus hook

beneath the tendon it is forcibly drawn upon until the cornea is partly buried at the opposite canthus. This dragging of the eye may be repeated several times, gradually increasing the effect. The tendon may be grasped with forceps and the eyeball alternately dragged back and forth. Or for very thorough stretching the hook may be passed under the opposing rectus. Thorough stretching is quite painful.

Division of check ligaments has been done as a means of increasing the excursion of the eye in the direction of the divided ligament; but the recorded experience is not sufficient to establish its effect. Parinaud (*Bull. et Mémoires de la Société francaise d'Opht.,* 1893, p. 291) divided the conjunctiva and subconjunctival tissue parallel to the corneal margin half way to the canthus; and worked down by the sheath of the muscle until firm resisting tissue was encountered, which was divided.

Exsection of tendons. The older tenotomists divided the tendon or muscle far back when they wished to correct an extreme deviation, and sometimes excised the stump of tendon left by such a division. An operation of this kind may exceptionally be of service by eliminating the influence of a muscle left unopposed by the functional destruction of its antagonist.

Prince (*Am. Jour. of Ophth.,* 1902, p. 259) who reported a series of cases treated in this manner, recognizes four indications for this operation on the antagonist muscle: (1) Permanent atrophy or paralysis. (2) Irrecoverable loss of either rectus through accidental section of the muscle back of the capsular perforation. (3) Extreme over-correction of long standing, following tenotomy. (4) Irrecoverable traumatic dislocation of the rectus. The muscle is to be taken up back of the point at which it pierces the capsule of Tenon. A sufficient portion of the length is isolated by use of the strabismus hook and scissors. This part of the muscle is then excised and the wound closed with a conjunctival stitch. At the same time such advancement as it is capable of may be done on the previously disabled muscle. The range of usefulness of such operations will diminish with the adoption of lateral transplantation of the tendons of insertion.

Excision of capsular tissues. The close connection of the muscle sheaths and tendons with the capsule of Tenon, check ligaments and other connective tissues of the orbit makes it possible to modify the position of the eye and the influence of a particular muscle upon the movements, without directly disturbing the muscle or its tendon of insertion. Dieffenbach (*Die Operative Chirurgie,* Vol. II, p. 116) stated that he had cured a "great number" of persons who squinted slightly, by excision of a piece of conjunctiva over the insertion of

the weakened muscle. This excision or cauterization of the tissue, either by the actual cautery or with silver nitrate, was done for paralytic squint, or the lowest grades of "active squint." Cauterization was repeated until marked thickening and contraction of the tissues was produced. This treatment was resorted to where it was feared that tenotomy would produce an excessive effect.

Excision of tissue is an important part of many advancement and shortening operations. In these, along with the tendon, parts of the capsule are usually removed. Sometimes, however, the tendon has not been included in this excision which, with the advancement, has been confined to the capsule and conjunctiva, as in the following operation suggested by Fox (*Tr. Sec. on Ophth. A. M. A.*, 1900, p. 68) for divergent strabismus.

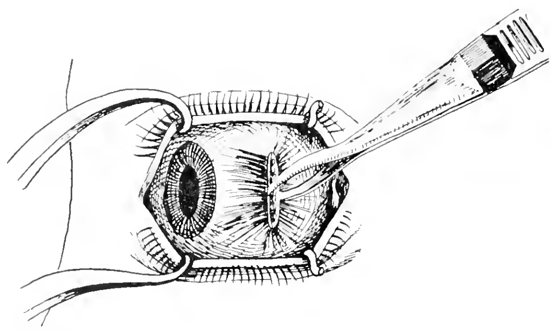


Fig. 72.
Method of Excision of Capsule and Conjunctiva for Divergent Strabismus. (Fox.) Tissues grasped in forceps ready for excision.

After tenotomy of the externus, the neighboring conjunctiva and capsule are thoroughly stretched by introducing a strabismus hook into the opening of the capsule, turning it first above and then below, and dragging the eyeball inward until the cornea is buried at the inner canthus. The tissues over the insertion of the internus are then grasped with special forceps, as shown in Fig. 72, midway between the cornea and caruncle. The forceps are raised two or three times to take up redundant tissue. As much of Tenon's capsule as possible is included, but not the tendon of the rectus. The tissue grasped by the forceps is then cut off with one sweep of curved scissors. This leaves an elliptical opening which is closed by four sutures placed as shown in Fig. 73. The immediate effect aimed at is a convergence of 1 to 4 mm.

Advancement of capsule was done by Parinaud (*Compte rendu des Séances de l'Académie des Sciences*, 1890, cx, p. 805) for convergent

strabismus. It includes the excision of a vertical fold of the conjunctiva at the outer side of the cornea. This is to be closed with sutures after opening the conjunctiva at the insertion of the internus, isolating the tendon by incision along its margin and completing the detachment of the capsule by cutting upward and downward from the insertion. In this way Parinaud claimed a change in the direction of the eye of about 15 or 20 degrees could be obtained, which might be increased to 25 or 30 by also dividing the insertion of the internus. The sutures were placed much as by de Wecker for advancement.

Partial fixation of globe was devised by Colburn (*Am. Jour. of Ophth.*, 1906, p. 85) to secure minimum nystagmic movement in the most useful part of the field of fixation; and to improve the position of the eyeball in cases of complete paralysis. The eyeball is held in

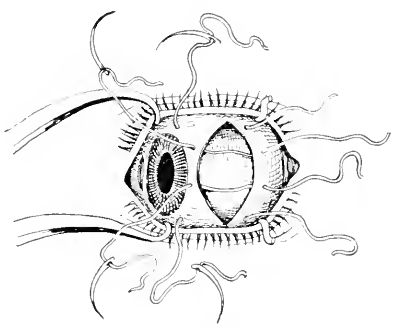


Fig. 73.
Advancement with Excision. (Fox.) After Removal of Tissue and Introduction of sutures.

a central position, while a small incision is made in the temporal cul-de-sac of the conjunctiva. The eye is then rotated strongly inward, the cut just made is enlarged to expose the external rectus muscle. The tissue is then excised outward to the periosteum, a double-armed suture is passed through the external muscle, then deep into the periosteum and out through the skin, at the outer angle of the orbit; where it is tied over a button of plate tin, being sufficiently tightened to hold the eyeball in the desired position. The effect of the operation is to greatly limit the lateral movements of the eye, while leaving it fairly free to turn upward or downward.

These *general indications for muscle operations* are done to rectify the position and improve the mobility of the eye. The muscles concerned are generally normal in structure, and capable of the same physiologic contractions as the corresponding muscles of normally directed eyes. Comitant strabismus, for which these operations are

usually done, is not essentially a defect of muscular action, but a fault of co-ordination. To correct a co-ordination, a function of the brain centers, by alterations in the peripheral instruments through which brain impulses act, is an indirect and palliative treatment. And considering the delicate accuracy of the ocular co-ordinations and movements, operative interference is only a clumsy means of approximate adjustment. *Operation is not to be thought of until the modification of nerve impulses, by the wearing of lenses, regulation of eye work, use of mydriatics, or myotics, fusion training, etc.*, have been properly tried and cannot be expected to bring about a better action on the part of the eye muscles. Operation should not be decided on without rather prolonged study of the case and trial of other measures. The trial of correcting lenses requires months or years. We should even take into account the chance of gradual better development of the co-ordinating centers, and the slight tendency to divergence that comes with increasing age.

The operative correction of the defect is at best only approximate. It brings about cure only in so far as it is followed by readjustment of nerve impulses. Such a readjustment of impulses, such an attempt to secure a more complete physiologic balance, is rendered possible by a wise disturbance of established relations; and occurs after every operative interference with the ocular movements. But such readjustments are more extensive, more complete, more permanent, more serviceable, and are accomplished with less annoyance, in proportion to the youth of the patient. In many cases we must confess inability to control the source of nerve impulses. All that we can do is to adjust the mechanical relations of the eyeball to its muscles in such a way that the nerve impulses and system of co-ordination that the individual has developed will give the best mechanical results; provided that under the use of glasses, and other means of treatment, these have probably reached a permanent state.

Any proper consideration of operation necessarily supposes a previous careful study of the kind and degree of motor anomaly present. The amount and direction of the deviation, its constancy or variations under conditions of general health or exhaustion, rest or use of the eyes, are to be previously known. For low degrees of deviation this demands considerable development and intelligence on the part of the patient, and operation should not be undertaken without the indications they furnish. But for gross anomalies of movement, careful repeated objective studies will furnish the data required, and operation may be done without such minute exactness; but not without certainty as to the general character and permanence of the strabismus present.

Effect aimed at. The degree of deviation is commonly measured in:

Degrees, as on the arc of a perimeter or tangent scale.

Millimeters of displacement of the pupil or cornea, measured on the eyeball or edge of the lid.

Prism degrees, or centrads, or prism dioptres, as measured by prisms, the deviation being about one-half the degree of refracting angle, by which the prism is numbered.

One millimeter of displacement is about five degrees of deviation. Each degree of deviation is equal to 2 prism-degrees, or two centrads or two prism dioptres.

In planning an operation it is convenient to estimate the change to be produced in the direction of the eye in millimeters. This unit with its easily estimated fractions is as small as it is practical to consider, in estimating what is being done in a surgical operation. Attempts to be more exact, by resorting to subjective tests to estimate the result obtained, are more likely to introduce error than to increase exactness.

In estimating the probable effect of a given change in the position of the attachment of a certain ocular muscle, we must distinguish between two totally different conditions, A and B.

A. If we advance the tendon of the internal rectus muscle 3 mm. leaving the external rectus in normal condition, the increased tension will not be thrown wholly on the externus, turning the pupil 3 mm. toward the nose. The increased tension will be divided between the two muscles. Each will be elongated one millimeter and a half. In the same way after simple tenotomy of the internus with the new insertion 4 mm. back of the old, the retraction has occurred half in the internus and half in the unopposed externus, and the eye will be turned only 2 mm. outward.

B. When, however, along with advancement of one muscle we do tenotomy of its opponent the effect produced on the direction of the eye is approximately equal to the distance of displacement of the muscle insertions. Thus, if the internus be advanced 4 mm. and the externus at the same time divided, the tendency of the latter to draw the eye out being removed, the turning of the eye in by operation will be the full 4 mm. of the displacement of the insertion. Indeed it may be more than this, because of contraction of the advanced muscle, which can act on the eyeball through the suture while the opponent is still unattached.

In attempting to correct upward and downward displacements the same differing conditions must be recognized. In dealing with torsions we never divide the opponents, and the case falls under class A. Indeed so many muscles are concerned in torsion that the displacement

of insertion should be more than double the change of angle desired.

Choice of operation. Theoretically, any case of strabismus might be treated by tenotomy of one muscle or advancement of another. For many years the operation commonly practised, or written about, was tenotomy. Other operations, as advancements, were scarcely considered, except as correctives or adjuvants of tenotomy. Of late years the bulk of the literature refers to advancement. One might judge from what is written that tenotomy was superseded, and relegated to a subordinate position. But this is not the case. In the hands of careful surgeons tenotomy is an extremely valuable operation; and the proper method of treatment for a large class of cases. The relative merits of tenotomy and advancement cannot be entirely settled until the latter has had its day as a fad, and its failures and bad effects have been as unsparingly published and criticized as have been those of tenotomy. In the end the choice of operation will necessarily remain a matter for individual judgment. It is only possible here to review those facts and considerations that should be carefully weighed in coming to a conclusion.

After successful tenotomy the insertion of the tenotomized muscle is farther back on the eyeball; after advancement it is farther forward. The influence of this change on the ocular movements has already been adverted to in the account of the contact arcs and the check ligaments. Briefly tenotomy causes diminished, and advancement increased, power and range of ocular movement. This is graphically represented by Landolt (*System of Diseases of the Eye.* Edited by Norris and Oliver, Vol. IV, p. 111). This reasoning, however, assumes that the advanced muscle actually acts upon the more anterior position at which it has been attempted to attach it. But it has been claimed that after advancement the tendon becomes attached as far back as its former insertion. Velhagen (*Klin. Monatsbl. f. Augenh.*, 1909) found this the case. As pointed out in connection with the contact arcs such attachment does not give the advantages claimed. Greater power and range of movement are good things; but their importance can be over-rated. The periphery of the field of fixation is little used in practical affairs. The available field is much more diminished by an ordinary pair of glasses than by the effects of a carefully planned and executed tenotomy. In high degrees of squint a good tenotomy will often actually increase the extent of the field of fixation, as well as make it more serviceable.

The gradation of effect is of greater practical importance in determining the choice of operation. Here advancement has rather the advantage. In tenotomy the cut muscle is retracted to an extent

not exactly controlled by the technique of the operation. But an advancement can be better proportioned to the effect desired. Very slight effects may be produced, however, by partial tenotomy; and the effects of complete tenotomy of the internus may be increased by extending it to the adductor portions of the superior and inferior recti. This extension is also capable of gradation to meet the needs of the particular case, by variations in the extent to which the secondary adductors are divided.

Advancement is graded by the placing of the suture or sutures and the extent to which the tissues are drawn up by the traction of the sutures. It is customary to watch closely the effect produced during the operation and to modify the division of the tendon or the tension of the sutures to meet this immediate indication. But this ought not to be depended on to the neglect of careful calculation beforehand of the exact effect to be aimed at; and careful planning of the extent of the division of the tendon to be attempted, or the exact position in which a suture is to be placed. Careful plans based on fair experience will give better final results than attempts to obtain the correction desired by watching the immediate effect, and modifying the operation according to its indications. Only when some unforeseen factor intervenes and the effect produced proves quite different from that expected, is it wise to modify a carefully prepared plan of operation. Under the stress of operation with local anesthesia, the patient's answers as to the subjective tests become especially unreliable. The careful recording of experience as a basis for judicious planning of an operation has been discussed by Asmus (*Zeits. f. Augenheilk,* v. 29, p. 422).

The operative disturbance of tissue is less with tenotomy than with advancement. Simple incision is always less of a disturbance than bending, twisting and traction of tissues, maintained for days by the introduction of a suture of foreign material. The after treatment of tenotomy is more brief, simple and safe, is less unpleasant and burdensome than that of advancement or of tendon tucking. After tenotomy, if a dressing is used, it is discontinued at the end of a day or two; and no sutures or clamps remain to keep up irritation and require removal subsequently. Even after extended tenotomy involving accessory tendons no soreness is felt after two or three days, and there remains only the ecchymosis and a hyperemia of the seat of operation. After other operations there is a greater soreness and swelling and conjunctival discharge increasing until the stitches are removed and dressings omitted.

In general it is better to do a combined operation, or to operate on

more than one muscle than to attempt by increased disturbance of the parts to produce an effect greater than can be properly expected from the operation practised. When both eyes have equally good vision, and are about equally employed, it is best to divide any marked operative alteration between the muscles of the two eyes, as by doing tenotomy of both externi for extreme exophoria. But it is better to so choose and plan operations as to secure the necessary alteration of ocular movements without having to operate twice on the same muscle. An exception to this may be noted with reference to tenotomy of the external rectus which may be repeated without harm, and sometimes with greater effect at the second operation.

Choice of operation in comitant strabismus. Here we have only to consider the amount of deviation and how it can be corrected with the least risk and discomfort to the patient, and the greatest freedom from disfigurement or limitation of movement.

There is general agreement that the slightest changes are to be effected by partial tenotomy, or by slight advancement or tucking without division of the opponent. Greater effects are produced by complete tenotomy; still greater by decided advancement; and the greatest effects by advancement of one muscle with tenotomy of the opponent.

Very great effects secured by tenotomy of a lateral muscle alone are dangerous; because a condition of unstable equilibrium is established. The influences of both the primary adductor and abductor are diminished, and the lateral movements come to depend more on the secondary adductors and abductors. The primary adductor and abductor tend to bring the eye to a central position, the secondary adductors and abductors alone would carry it to extreme convergence or divergence. Hence when the influence of the latter preponderates, there is a strong tendency for the eye to again deviate as before, or in the opposite direction, from the influence of comparatively slight causes. Relapses, or eyes turned the other way, are among the effects of attempting to correct by tenotomy strabismus of too high degree to be properly amenable to that operation. After the above general review of the subject a specific recommendation of operations is permissible. The author prefers:

For excess of convergence, esophoria or esotropia. Less than 5 degrees (ten centrads or ten-degree prisms) partial tenotomy, central. (Stevens' method.)

Five to twelve degrees (10 to 24 centrads), advancement or tendon-tucking, without division of externus.

Twelve to fifteen degrees (2.5 to 3 mm.), complete tenotomy.

Fifteen to thirty degrees (3 to 6 mm.), extended tenotomy.

Above thirty degrees (6 mm.), advancement of the externus, with tenotomy of the internus, extended if necessary.

In squint of high degree over 20 degrees (4 mm.), operate on the deviating eye, attempting to correct two-thirds or three-fourths the total squint, and expecting to complete the adjustment by subsequent operation on the fixing eye.

For divergence or deficient convergence, exophoria or exotropia. As Duane points out in regard to convergence insufficiency: "Operation should not be done unless all other means have been thoroughly tried and have failed, and unless also the symptoms are severe and likely to be permanent."

Three to five degrees (6 to 10 centrads), complete tenotomy.

Five to ten degrees (1 to 2 mm.), advancement of the internus or free tendon tucking without division of the externus.

Ten to twenty degrees (2 to 4 mm.), advancement of the internus with complete tenotomy of the externus.

Twenty degrees and upward, advancement of internus with tenotomy of externus, and anchorage of eye to nose with threads. For higher degrees of divergence such an operation may be done on both eyes simultaneously. The threads may be cut if there seems to be danger of too great an effect. Or for a later adjustment increasing the effect, tenotomy of the externus may be repeated with or without the use of a thread anchorage to the nose.

Choice of operation for paralytic strabismus. Here other factors besides the degree of deviation have to be considered. In so far as the paralysis is absolute the ordinary operations of tenotomy and advancement are of little value. But in the great majority of cases some power is retained or recovered by the affected muscle or muscles.

There occurs, too, a gradual readjustment of muscular actions, so that the function lost becomes largely replaced, and the movements at first impossible can be executed by the contractions of muscles on which they do not normally depend. It might be supposed that a deviation caused by loss of power in a particular muscle should always be met by advancement of that muscle to increase its influence. But advancement fails to produce this effect if the power of muscle contraction has been lost; and loses its influence in proportion as this power is weakened. It is pre-eminently true of paralytic strabismus, that every case must be the subject of special study, if the operation best suited for its correction is to be chosen.

For illustration suppose a case of paresis of the right superior oblique. The most marked symptom is failure of the eye to turn down, but with some weakness of outward movement and some extorsion.

Even with an advancement of the affected muscle out of the question, the operative possibilities to be considered are quite complex. We might advance the right inferior rectus which normally assists the affected muscle in turning the eye down. Or we might do tenotomy on the right superior rectus, an antagonist of the superior oblique in vertical movements. Again we might do tenotomy on the left inferior rectus, or advancement of the left superior rectus in the hope of making downward movement as difficult for the left eye as disease has made it for the right. But advancement of the right inferior rectus, or the left superior rectus would rather increase the tendency to convergence. Again, tenotomy of either superior rectus, or advancement of either inferior rectus will tend to increase the extorsion, while advancement of a superior rectus, or tenotomy of an inferior will correct the extorsion. Taking all these things into account Alfred Graefe (Graefe's *Archiv. f. Ophth.*, XXXIII, pt. 3, p. 179) concluded that the indications were best met when paralysis of the right superior oblique was treated by tenotomy of the left inferior rectus. This would diminish the power of the left eye to turn down as the power of the right had already been diminished by disease. It would also diminish the tendency to convergence and would tend to produce an intorsion of the left eye that would balance the extorsion of the right.

But there are yet other factors that have to be taken into account. If the patient were compelled to use the eyes turned down, as in reading and in most kinds of close work, the diminution in the power to turn them down might be a serious drawback. If the eyes were habitually used turned down and to the right the disturbance of the turning down might be very much more important than the disturbance of torsion. In one case the inability to turn the eye down might be the only serious impairment of the patient's power. In another case the disturbance of torsion might over-balance everything else.

Operations to affect the vertical movements are almost always called for on account of some paretic condition, and the absence of details in reported cases leaves it impossible to estimate the effects to be expected from either tenotomy or advancement in a case of paralytic squint. Such lack of detail also renders worthless such statements as, more effect is produced by operation on the superior than the inferior muscle. Or that it is always better to do an advancement than a tenotomy for paralytic squint. In view of these facts any general statement as to the choice of operation would be worthless. Success is to be obtained by thorough repeated study of the deviations and limitations of movement present in the particular case; after the period of readjustment, always many months and better one or more years, from

the occurrence of the paralysis. The amount of effect we can expect from a given operation in comitant squint is roughly known; and in so far as operation is indicated in paralytic squint it may be expected to have a similar effect. But mostly there is in the latter class of cases less danger of an over-effect.

Returning to our illustration of operative possibilities in a case of paresis of the right superior oblique. If the limitation of movement were very slight one might do partial tenotomy of the right superior rectus; leaving the temporal fibres of the muscle undivided so as to increase its tendency to oppose extorsion, while diminishing its power of preventing the eye from turning down. If the disturbance of torsion were very slight and the vertical deviation great, the tenotomy of the right superior rectus might be made complete. If the patient were not required to do any accurate seeing with the eyes turned down, tenotomy of the left inferior rectus could be done. But if the effects of the paresis are more serious the lateral displacement of the right superior rectus, as devised by the writer, carefully adjusted to the conditions present is indicated. Only after some such review of therapeutic possibilities should one plan an operation for paralytic squint.

In regard to all operations on the extrinsic ocular muscles: Operate only after thorough study of the case, including trial of appropriate non-operative treatment. The final result of operation may only be reached after many weeks or months, but failure to correct the defect may be evident to all who know the patient so long as he lives.—(E. J.)

Muscles, Operations on the eye. See **Muscles, Ocular.**

Muscles, Orbital. See **Muscles, Ocular.**

Muscles, Tumors of the eye. New-growths of the extrinsic ocular musculature are comparatively rare. The Editor has reported a lipoma of the external rectus. Pascheff (*Ophthalmic Year-Book*, p. 322, 1909) has given a history of three cases of tumors involving the extraocular muscles, and brings together under a systematic arrangement previously reported cases. His classification is: 1. Malignant tumors: A. Sarcoma primary, of intraocular origin, or metastatic. B. Metastatic cancer. 2. Benign tumors: Fibroma, angio-fibroma, angioma, lipoma and cysticercus. 3. Pseudo-tumors: Gummas, tubercular, syphilitic, hyaline degeneration and ossification.

Pascheff's first case was one of sarcoma intimately associated with the superior rectus muscle. The eyeball was shrunken. The contents of the orbit were removed, but the subsequent history of the patient is not stated. The second case was one of lipoma of the external rectus, the size of a kidney bean, in a girl of 14. On removal it was found to be a lobulated lipoma adherent to the muscle. The

third case was one of cysticercus involving the external rectus, occurring in a woman of 24. It was the size of a small pea, and adhered firmly to the body of the muscle. It contained the scolex of the cysticercus. In two of the cases reported by Napp round-celled sarcomas appeared to have originated in the internal rectus muscle. After exenteration of the orbit there was no recurrence in 18 months. See, also, **Tumors of the eye.**

Muscle, Tensor tarsi. HORNER'S MUSCLE. See p. 6023, Vol. VIII of this *Encyclopedia.*

Muscoli dell'occhio. (It.) Muscles of the eye.

Muscular anomalies. See **Heterophoria**; and **Heterotropia**; as well as **Muscles, Ocular.**

Muscular asthenopia. Asthenopia dependent on inherent weakness of the external or other muscles of the eyes. See **Asthenopia, Heterophoric,** p. 652, Vol. I of this *Encyclopedia.*

Muscular insufficiency. HETEROPHORIA. A condition in which a muscle (especially one of the ocular muscles) is relatively weak compared with its antagonist, so that an effort on the part of this muscle is required in order to maintain equilibrium.

Musculus ciliaris Riolani. A slip of muscle fibre derived from the orbicularis palpebrarum and running along the free border of the lid, behind the eyelashes.

Musculus crystallinus. See **Crystalline muscle,** p. 3576, Vol. V of this *Encyclopedia.*

Musculus frontalis verus. (L.) Corrugator supercilii.

Musculus oculi choanoides. See **Choanoid muscle,** p. 2072, Vol. III of this *Encyclopedia.*

Musculus orbitalis. An unstriped muscle arising from the orbital periosteum and inserted into the fascia of the interorbital fissure. It is innervated by the sympathetic and is supposed to take part in protruding the eyeball, as in, e. g. exophthalmic goiter.

Musculus palpebralis. Mueller's muscle.

Musculus rectus lateralis. External rectus muscle.

Musculus rectus medialis. Internal rectus muscle.

Musculus supercilii. (L.) Corrugator supercilii.

Musculus tarsalis inferior. MUSCULUS PALPEBRALIS INFERIOR. The fibres of Mueller's muscle supplied to the lower lid.

Musculus tarsalis superior. That part of Mueller's muscle supplied to the upper lid.

Musculus trochlearis. Superior oblique muscle.

Muscusan. A proprietary preparation of zinc dibordiortho-oxybenzoate; used as a bactericide.

Museum preparations of the ocular tissues. See the major heading, **Laboratory technique,** p. 6886, Vol. IX of this *Encyclopedia.*

Music, Color-. See **Color-music,** p. 2401, Vol. IV of this *Encyclopedia.*

Muskelpinzette. (G.) Forceps used in muscle operations.

Muskelschere. (G.) Muscle scissors.

Muskeltrichter. (G.) Extrinsic ocular (muscle) cone.

Mussænda frondosa. A small East Indian tree. The bark is used in diarrhea, and the juice of the leaves as an eye-wash in caligo corneæ.

Mussel. In ancient Greco-Roman days, mussels were now and then employed as ophthalmic remedies. Sea-mussels, salted and reduced to ashes, were mixed with resin of cedar and applied to the margins of the lids to prevent the return of cilia after epilation. The *Mytulus edulis,* reduced to an ash and well washed, was supposed to remove corneal cicatrices. Finally, the *Aphysia depilans,* reduced to an ash, was esteemed as an ocular depilatory.—(T. H. S.)

Mustard. *Sinapis.* This genus of plants of the natural order *Cruciferæ* has at least three species, all annuals, that contribute their seeds to the manufacture of mustard. *Black mustard (S. nigra)* is a native of the middle and the south of Europe; a rather coarse plant, two or more feet high, having the lower leaves lyrate and usually hispid, the upper leaves linear-lanceolate, entire, and hairless. The flowers are yellow, in slender racemes. The pods rarely exceed ½ in. in length, closely pressed to the stem. The seeds are deep-brown. *White mustard (S. alba),* a native of southern Europe and western Asia, has been naturalized in the United States. The whole plant is more or less hairy, the leaves pinnately lobed. The flowers are large compared with those of the preceding species; the pods nearly twice as long, with a long flattened beak, and five prominent nerves; and the seeds are pale yellow. The *wild mustard* or charlock (*S. arvensis*) is a weed of cultivation only too common in Britain and in some parts of the United States. It is from the ground seeds of the two first named that mustard is chiefly obtained, but those of the last named are also used in the manufacture of that condiment. Much of the mustard seed imported from India is Sarepta mustard (*S. juncea*). Mustard is often adulterated; but "mustard condiment," made of mustard flour and wheaten flour or starch flour, is less bitter and stinging than pure mustard, and keeps better. Both black and white mustard seed yield by expression a non-drying fixed oil, which is known as *oil of mustard,* and is free from pungency. When treated with water it immediately becomes powerfully irritating to the skin.—*(Standard Encyclopedia.)*

In ancient Greco-Roman times mustard was highly esteemed as a remedy for numerous affections of the eyes. The juice mixed with

honey enjoyed an especial reputation in trachoma and amblyopia; grated mustard, with water, wax and honey, was employed as a routine remedy in palpebral ecchymosis; while, as a general strengthener of the vision, the juice of the seeds and stems was drunk.—(T. H. S.)

Mutterkorn. (G.) Ergot.

Mutton-fat keratitis punctata. A name sometimes given (in England) to that form of chronic cyclitis in which the deposits on Descemet's membrane assume a yellowish, gelatinous appearance.

Muzzy, Arthur T. An ophthalmologist and otologist of New York City, who was born in India, the son of a missionary, in 1852. He graduated from Amherst College in 1874, and from the College of Physicians and Surgeons of the City of New York in 1879. He was assistant surgeon at the New York Eye and Ear Infirmary, and consulting oculist and aurist to the Gabella Heimat.—(T. H. S.)

My. An abbreviation sometimes used for *myopia.*

Myasis. Ocular myiasis. Injury (to the eyes) by insects or other parasites.

Myasthenia. Muscular weakness.

Myasthenia gravis, Ocular symptoms. This affection, also called Erb's disease or asthenic paralysis, has many of the characteristics of bulbar paralysis. Ptosis is an early symptom in 50 per cent. of the cases, and occurs sooner or later in about 85 per cent. of the cases. External ophthalmoplegia and paralysis of the orbicularis palpebrarum are frequent, for ophthalmoplegia interna seldom occurs. Defective upward movement of the eye, with fair preservation of lateral and downward movements, is noted. The muscular paresis is more marked on fatigue (Weeks).

Nystagmoid movements are occasionally seen. Strabismus and diplopia are common, usually due to weakness of the superior and external ocular muscles.

The degree of muscular fatigue may be tested by the *ergograph* (see p. 4698, Vol. VI of this *Encyclopedia*); it may also be demonstrated by faradic stimulation—the so-called myasthenic reaction. Marked atrophy of the muscles concerned does not usually occur. Although in this disease the musculature of the mouth, tongue and palate are generally affected, as well as the muscles of the eyelids and orbit; it occasionally is confined to the latter group alone, as in a case reported by Smyth (*Dublin Journal of Medical Science*, Oct., 1914). The patient developed ptosis and diplopia, but was otherwise well, not tiring readily. Under three months' treatment by tuberculin, the ptosis disappeared, and diplopia occurred only on the effort to move the eyes upward.

Myasthenia palpebralis. Any interference with the functions of the orbicularis palpebrarum muscles, but particularly with their synchronous or bilateral contraction or relaxation in closing or opening of the eye or eyes. In some cases the patient cannot disassociate these movements; he cannot wink or shut one eye alone. This anomaly may be either congenital or acquired; it may be due to organic disease of the cord or of the motor supply to one or both muscles or it may occur as a psychic phenomenon. A complete exposé of this subject—especially in its varied neurologic aspects—is given by Prosper Merklen (*Gazette des Hôpitaux,* 85, p. 171) to which the reader is referred.

Myatony. MYOTONIA. Deficiency or absence of muscular tone.

Myautonomy. A condition in which muscular contraction aroused by stimulation is so long delayed that it appears to occur independently of the stimulation.

Mycelium. The vegetative body of a fungus composed of a mass of filaments called *hyphæ.*

Mycetism. Mushroom-poisoning.

Mycetogenic. MYCETOGENOUS. Caused by fungous growths.

Mycobacterium tuberculosis (Koch). The cause of tuberculosis of the conjunctiva, and other parts of the eye.

Mycodermatitis. Inflammation of a mucous membrane.

Mycohemia. The presence of bacteria in the blood.

Mycology. The science and study of fungi.

Mycolysine. A preparation of plant-cells, alcohol, milk ferments, and non-pathogenic bacteria: used to excite phagocytosis in the human body in the treatment of cancer and tuberculosis.

Mycophthalmia. (L.) Fungous ophthalmia; any fungoid ocular affection.

Mycosis fungoides. Under this title a case closely resembling palpebral blastomycetes is reported by C. M. Kleipool (*Tyds. v. Geneesk.,* Jan. 9, 1915; abstracted in *Ophthalmology*). The patient, in June, 1913, showed an ulcer of the right inner ocular angle with firm border, which had progressed on the upper eyelid, and was pretty deep. After 20 *x*-radiations of one hour the discharge ceased, but much infiltration remained. In the beginning of 1914 much edematous swelling of the upper lid was present. Arsenic treatment had no success.

The patient stated that ten years before he had itching spots on his knee, also above the right eye, on which scabs appeared and which secreted fluid. Spots later appeared on the back and legs. They went and came and differed in size. As a child he had what his mother called ringworm. His only complaint was itching.

The patient looked rather older than his age of 55. He had a fist-

like tumor of the upper eyelid, 14 to 8 cm. large and about 2 cm. elevated above the surrounding parts. The tumor was in the skin and movable in its entirety; bluish-red, the surface moist through yellow, non-smelling discharge, soft, with pseudo-fluctuation. The borders of the tumor were sharply defined and firmer than the rest of the tumor. The eyelashes were gone. Vision was present on lifting of the lid. Patient had not much trouble; some itching, no pain; no swelling of the glands. At the left side of the forehead there was a large elevated patch, of lichen appearance, soft, sharp-limited. A few such spots were on other places of the body. Patient did not allow a histologic or blood examination. With Roentgen-ray treatment the tumor began to decrease. At the same time all the spots on the body began to heal; some disappeared altogether.

Mycosis, Ocular. This title covers any disease of the eye due to fungi. Landrieu (*Klin. M. f. Augenh.*, p. 123, July, 1913) has discussed these as a whole and has found in the literature nineteen of aspergillus keratomycosis, twenty of sporotrichosis, one of keratitis from verticillium, two of conjunctivitis from oïdium albicans, some more or less severe cases of blastomycosis of the lids, conjunctiva and cornea, several of favus and actinomycosis, twenty-three of concrement of the lachrymal canaliculi observed in France, and one case of conjunctivitis from streptothrix. All the fungoid infections of the eye are described in their proper places in this *Encyclopedia.* See, e. g. **Blastomycosis** and **Keratomycosis**; also, **Sclera, Mycosis of the.**

Mycotoxination. Inoculation with bacterial products.

Mydesis. 1. Putrefaction. 2. A purulent discharge from the eyelids.

Mydriasis. Dilation of the pupil. See **Pupil in health and disease.**

Mydriasis, Dyspneic. Mydriasis which occurs in dyspnea as a result, perhaps, of irritation of the sympathetic.

Mydriasis, Jumping. See **Mydriasis, Spasmodic.**

Mydriasis medicamentosa. (L.) Dilation of the pupil due to drugs.

Mydriasis, Psychic. Mydriasis from fright or other violent emotion.

Mydriasis, Spasmodic. Springing mydriasis. Jumping mydriasis. The original German title "Springende Mydriasis" is responsible for the terms "springing mydriasis" and "jumping mydriasis," sometimes applied to this rare form of pupillary dilatation. Cramer (*Klin. Monatsbl. f. Augenheilk.*, p. 201, 1911) reports a case of this curious condition. The patient was a child of seven, whose parents had noticed inequality of the pupils for a considerable time. Under examination their size varied in a peculiar manner. The pupil of one side would be dilated, but presently, without any alteration in fixation, it would contract, while the other became enlarged. The movements were not

rhythmic, but occurred at irregular intervals. The direct and consensual reaction of the pupils to light was normal. On convergence, at first both contracted equally, but if reading were continued the same peculiar play of the pupils recommenced. Accommodation was normal and not influenced by the dilated or contracted state of the pupils. The vision and fundi were normal. The child appeared to be quite healthy, and no history of past illness was elicited.

This symptom has often been regarded as the precursor or accompaniment of grave nervous disease, but in the present instance it seems not improbable that it was an unimportant peculiarity. No fully satisfactory explanation has been advanced; it has been attributed to irritation of the motor nuclei, or of the sympathetic, and has been compared with an athetosis under vaso-motor influences.

Mydriasis spastica. (L.) Dilatation of the pupil due to paresis or paralysis of the sphincter muscle of the iris.

Mydriasis spectacles. Spectacles which have, in place of lenses, discs whose centers are pierced by small holes.

Mydriasis, Springing. See **Mydriasis, Spasmodic.**

Mydriatic. Any agent that dilates the pupil is a mydriatic; one that paralyzes the ciliary muscle and the accommodation, is a cycloplegic. Every cycloplegic drug is without exception a mydratic but a mydriatic is not necessarily a cycloplegic. For instance, weak solutions of euphthalmin or cocain dilate the pupil, but have no effect upon a healthy ciliary muscle.

The important natural order of *Solanaceæ*, to which belong *Atropa belladonna, Hyoscyamus niger, Datura stramonium, Scopola carniolica,* and several other plants of minor importance, produce alkaloids and other agents that dilate the pupil and paralyze the ciliary muscle. These are chiefly atropin, hyoscin (scopolamin), hyoscyamin, duboisin, daturin, homatropin, euphthalmin, apoatropin, atropin santoninate, atrosein, belladonna, belladonnine, ephedrin, mydrin, eumydrin, methyl-atropine bromide, mydrol and rotoin. See, also, **Cycloplegic**; **Cocain**, and **Euphthalmin**; as well as **Mydrin.** The relations of the pupil to this caption are treated under **Pupil in health and disease.**

Mydrin. This is a white powder, a proprietary mydriatic (Merck) composed of one part homatropin to 100 parts ephedrin in a 10 per cent. aqueous solution, and intended to produce an evanescent mydriasis mainly for ophthalmoscopic purposes. After the use of one drop Oliver noticed that the pupil reaches its maximal dilatation of 4 to 7 mm. in 30 to 35 minutes, and returns to normal in four to six

hours' time. The mixture is more effective as a mydriatic than either of its constituents alone.

Groenouw used the following as a substitute for mydrin: Ephedrin. hydrochlor, gr. vii; Homatropin, gr. 7/100; Aquæ dest., ʒ iiss.

The dilatation of the pupil begins shortly after instillation and remains at its maximum for half an hour, thus affording ample time for an ophthalmoscopic examination.

Mydrol. Iodomethylphenylpyrazolon. A white, odorless, bitter powder, soluble in water and alcohol but insoluble in ether. In 5 to 10 per cent. aqueous solution it has been recommended as a mydriatic and substitute for euphthalmin.

Myectomy. Excision of a portion of muscle.

Myectopia. Myectopy. Displacement of a muscle.

Myelin. Any one of a certain group of lipoid substances found in various normal and pathological tissues and differing from fats in being doubly refractive.

Myelin cataract. Formerly, a shrunken, disc-shaped cataract the chief constituent of which is a half-transparent, yellowish or brownish, dry and friable substance. When operated upon, these cataracts split in all directions and are removed with great difficulty.

This term is sometimes applied to an incipient cataract between whose fibres are occasionally found microscopic droplets of myelin.

Myelitis, Ocular relations of. Neuromyelitis optica. Inflammation of the spinal cord. The symptoms of myelitis vary with the character and location of the lesion. They are, in general, pain in the back, girdle-sensation, hyperesthesia, formication, anesthesia, motor disturbances, paralysis, increase of the reflexes, paralysis of the sphincters, bed-sores, and, in the later stages, spasmodic contractions of the paralyzed limbs. The disease may or may not be due to syphilis. It is fatal in about half of the cases.

The eye signs and symptoms are chiefly referable to the intrinsic ocular muscles and the optic nerve.

A case of dorsal transverse myelitis with *retrobulbar neuritis* and *slight papillitis*, was reported by Erb and Steffan in 1879. Since that time about fifty cases of optic neuritis associated with myelitis have been published. In some cases the picture of a pronounced choked disc was present, in others visual disturbance without ophthalmoscopic signs, points to retrobulbar neuritis. Primary optic atrophy is rare, as also partial atrophy affecting the temporal side of the disc. The retina is usually free from abnormality. The visual disturbance generally amounts to complete amaurosis which is commonly transient but eventuates in complete amblyopia. There is often an interval of a

few days between the affection of the two eyes. Pain on movement of the eyes, and other signs of retrobulbar neuritis may be present. The optic affection may precede signs of myelitis by days or months, usually only a short period. The symptoms may be simultaneous; rarely those of myelitis precede those of optic neuritis. The field of vision varies greatly in different cases—temporal hemianopia, central scotoma, concentric contraction, have been observed. Where it has been possible to make an anatomical examination, the optic nerves show changes analogous to those in the cord—softening, degeneration of the fibres, neuroglial proliferation, etc. In most cases the optic nerves, chiasma, and tracts have all been involved; occasionally only the optic nerves. Isolated affection of the chiasma or tracts does not occur. The inflammatory nature of the process is admitted by all authors. The pathogenesis of the disease offers peculiar difficulties. There can be no doubt that the myelitis and optic neuritis depend upon the same underlying cause (Parsons). The disease is met with in patients whose ages have ranged from 12 to 60 years, and males are more frequently affected than females. Cobbledick (*Ophthalmoscope*, Jan., 1910) in reporting a case, suggests that with modern methods of recognition, syphilis may now be found to play a prominent part in the production of this rare symptom-complex.

In some forms of *acute myelitis double optic neuritis* is, according to E. F. Clowes and F. Taylor (*Lancet*, Mar. 23, 1912) occasionally seen. To this condition the name *neuromyelitis optica* may be given. The optic neuritis generally precedes the myelitis by some days or weeks; but it may occur simultaneously, or first appear some days after the onset of the myelitis. The neuritis is in some cases only shown by a temporary amaurosis; in others there is obvious papillitis. The myelitis is, as a rule, not different in its symptoms and course from myelitis unassociated with an ocular lesion. The prognosis must depend on the severity of the myelitis, and the mortality has been about 50 per cent. The optic neuritis has often subsided, and vision has been recovered.

Pathologically, the lesion of the cord is a diffuse or disseminated myelitis, affecting either the cervical or dorso-lumbar region, or both; and histologically, in some cases, numerous endothelial cells undergoing fatty degeneration have been found around the vessels in the affected parts. To these importance has been attached by some authors, but others are satisfied that such elements are not peculiar to those cases. In a few of the fatal cases some indications of encephalitis have also been present. In two cases by Auerbach there was clinical evidence of the cranial nerves being involved; and in the

reported case there were noted a diminution in the sense of smell and loss of taste in the left half of the tongue. See, also, **Neurology of the eye.**

Myeloidin. A substance resembling myelin, occurring in the pigmented epithelial cells of the retina.

Myeloma. Any medullary tumor; giant-cell sarcoma; tumor of the bone-marrow.

Myiasis. Betti (*Klin. Monatsbl. f. Augenheilkunde*, February-March, 1915), of Siena, has seen four instances of insect larvæ in the human conjunctiva in two years. In the first case a woman complained of pain due to an insect flying into the right eye. This had happened a few hours earlier, and although she was sure that the insect had only struck the eye momentarily, the pain had increased and there was a feeling as of a sharp foreign body moving between the eye and eyelid. Next day the pain was still more severe. The lids were found to be red and swollen, and there was hyperemia of the conjunctiva and mucopurulent secretion. The conjunctiva was dotted over with small vesicles. The cornea and iris were normal. A white, larval organism was detected in the fold of the conjunctiva, wriggling about on the surface. Others were discovered, and several were removed. Lotion and a mercurial ointment were prescribed. During the next day or two the patient developed pain in the nose and throat, accompanied by catarrhal secretion containing similar larvæ. The condition extended to the antrum of Highmore and to the middle ear.

The other three cases were somewhat similar, except that they did not suffer from extension to the nose and other parts.

In all four cases the organism was the larva of the *Œstrus ovis,* the fly which lays its eggs in the nares of the sheep.

Myiasis in man is rare in central Europe, but relatively frequent in Russia. The two European species are the *Œstridi* and the *Muscidi,* and of the former the most important are the *Œstrus ovis* and the *Œstrus bovis.* The affection due to *Œstris ovis* in man's eye may be said to be an innocent form of myiasis, in spite of the severe complications of Betti's first case, for it does not attack healthy tissues, in contrast with the *Muscidi* which cause actual destruction of tissues, attacking the cornea, iris, lens, etc., and may even lead to the death of the host. This is especially true of *Lucilia macellaria,* which is found in tropical countries. In cases like those seen by Betti, the treatment consists in removing the individual larvæ by means of a pipette or forceps, and applying a mercurial ointment after douching the conjunctiva. If the larvæ should be found in the anterior chamber or under the conjunctiva, surgical methods must be employed.

Myiocephalon. (L.) The protrusion of a minute portion of iris through a perforation of the cornea. So called on account of its resemblance to a fly's head.

Myiodeopsia. (L.) That condition of the eye in which muscæ volitantes are perceived.

Myiosis. MYIASIS. Any disease caused by maggots or flies.

Myitis. Inflammation of a muscle; myositis.

Mylowitis. MOUSE-EAR. In Greco-Roman antiquity, employed in various diseases of the eye.

Myo-. A prefix denoting some relation to a muscle or to muscles.

Myoatrophy. MYATROPHY. Muscular atrophy.

Myoceptor. The structure in a muscle-fiber that receives the nerve stimulus from the motor end-organ of the nerve.

Myochrome. Any member of a group of muscle pigments.

Myochronoscope. A device for measuring the time required for a motor impulse to become effective.

Myoclonus, Ocular. MYOCLONIC NYSTAGMUS. This term is applied by Ernest Thomson (*Lancet*, p. 167, Jan. 18, 1913) to a condition first described by von Graefe as "an accompaniment of a general contraction of ocular muscles excited by contraction of the orbicularis due to simultaneous excitation of the nuclei of the seventh and third nerves." The author's illustrative case seems to support the Mendelian theory of the innervation of the orbicularis and the occipitofrontalis as eye muscles by the third nucleus via the seventh nerve. Thomson is unable to determine its exact place in medical terminology but thinks it might be found by the neurologist.

The patient, aged 18 years, was a printer by trade. He is an orphan so that there was no family history obtainable. He was first seen in October, 1912. He had been subject to attacks of closing of the left eye associated with headaches and sickness since birth, as he understood, or, at any rate, as long as he could remember. The present attack was one of the worst he had ever had, and caused loss of appetite. The left palpebral fissure was smaller than the right, owing to slight permanent drooping of the upper lid. There were rhythmical contractions of the left orbicularis palpebrarum and occipito-frontalis at the rate of 72 contractions per minute. The contractions were not sufficient actually to close the eye. Every now and then the contractions became irregular. There was contraction and dilatation of the pupils in association with the muscular spasm which was not a light reflex. Ophthalmoscopically there was no indication of spasm of the ciliary muscle. The right eye was emmetropic, R. V. 5/5, the left was hypermetropic, about 4.0 D. L. V. 5/36, not improved. Fundi normal.

On the first occasion only, when the spasm was at its height, there were seen slight rapid nystagmic movements in the right eye; similar movements were not observed in the left eye. The contractions of the orbicularis-occipito-frontalis were only rhythmical on the first occasion; on subsequent visits they were irregular. The influence of bromide having had an immediate relieving influence, the nervous system was examined by Barclay Ness who found nothing abnormal outside the ocular symptoms. He considered there was a certain amount of paresis of the orbicularis and occipito-frontalis due to long-continued spasm. Subsequent observation showed that bromide only lessened the intensity and abolished the rhythmicality of the spasm. The contractions went on from day to day and week to week, sometimes more, and sometimes less troublesome to the patient. The most interesting feature appears to be the association of the seventh nerve of one side with the third nerve of both sides.

Myodesopsia. MYODOPSIA. Obsolete names for subjective visual sensations, like muscæ volitantes. See **Myiodesopsia.**

Myodynamometer. A device for testing the power of the muscles.

Myofibril. A muscle-fibril; especially one of the fine fibrils traversing longitudinally the cells of smooth muscular tissue and supposed to form the contractile element.

Myoglia. A fibrillar substance formed by muscle-cells and bearing the same relation to muscle that neuroglia bears to nerve-cells.

Myograph. An apparatus for recording the effects of a muscular contraction.

Myokinesis. Movement of muscles; especially, displacement of muscle-fibers in operation.

Myokymia. Persistent quivering of the muscles, as in blepharospasm.

Myolemma. The sarcolemma.

Myology. The sum of knowledge regarding the muscles.

Myoma of the eye. New-growths composed entirely or largely of muscle tissue are rarely found in conjunction with the ocular organs, in spite of the fact that the eye is liberally supplied with muscle tissue.

Myoma of the iris, apart from ciliary myoma, is almost never seen, although Griffith has described a solitary example.

Myoma of the choroid. Ball (*Modern Ophthalmology*, p. 420) says that this tumor has been found several times in the choroid. In the case reported by Guiata, of Siena, the diagnosis rested between a subretinal cysticercus and choroidal neoplasm. The case was that of a man, aged 20 years, whose vision had been failing for months. The ophthalmoscope showed a rounded elevation. Repeated examinations failing to show movement in the mass, the diagnosis of choroidal tumor

was ventured, and an enucleation was performed. The tumor measured eight by five millimetres, and extended from the ora serrata to the equator. Microscopic examination showed it to be a myoma of the choroid.

Myoma of the ciliary body. Weeks describes a case in his own practice. It occurred as a globular tumor, measuring 7.5 mm. in diameter. It developed very slowly without producing pain, finally causing diminution of vision by partial opacification of the lens and by serofibrinous exudation. It was supposed to be a sarcoma. Microscopic examination showed it to be composed of non-striated muscle fibers, densely packed in an irregular, concentric arrangement. See, also, **Tumors of the eye.**

Myometer. An apparatus for measuring muscle contraction.

Myonosus. Disease of a muscle.

Myonymy. Nomenclature of the muscles.

Myopathy. Any disease of a muscle.

Myope. One affected by myopia or shortsightedness.

Myope, Chromic. A person whose color-vision is normal for objects within certain distances but to whom all colors beyond that limit appear neutral gray.

Myopia. HYPOMETROPIA. BRACHYMETROPIA. NEAR SIGHT. This form of ametropia is considered under **Refraction of the eye,** as well as under **Ametropia; Examination of the eye; Care of the eye,** p. 1418, Vol. II, and p. 3186, Vol. V of this *Encyclopedia,* yet it may be added here that the form of nearsightedness known as myopia occurs when the retina is situated behind the principal focus of the eye, and parallel rays, after having come to a focus in the vitreous body, become divergent and form a circle of diffusion on the retina.

The refraction power of the myopic eye is so high, or its axis is so long, that, in a state of rest, parallel rays are not united upon the retina, but in front of it. Only divergent rays can form a focus on that membrane. The *punctum remotum* of the myopic eye is positive and is situated at a finite distance, and can be found by uniting the convergent rays emerging from the eye. The retina and the far point form conjugate foci.

The *punctum proximum* is always closer than in the emmetropic eye of corresponding age, and its position depends on that of the far point. The strongest concave glass with which the patient sees at a distance will give the position of the *punctum proximum*, and the refraction corresponding to the maximum amount of accommodation. To find the range, or amplitude of accommodation, it is necessary to know the refraction with the eye at rest, i. e., the amount of myopia, and the

measure of error is the weakest concave glass that adapts the eye to infinity. The difference between these two lenses marks the amplitude of accommodation (Landolt).

Clinically the *punctum proximum* in myopia is determined by the nearest point at which the patient can read fine print, or can distinguish the hairs of the optometer.

The myopic eye has as much lens power as is possessed by the hypermetropic or the emmetropic eye, but in the hypermetrope a certain amount is lost in maintaining distinct distance vision; thus, less power is available for focusing near objects. The myope, not being compelled to use any of the power for distance vision, has that much more for focusing near objects, and in addition is assisted still further by the long visual axis, which enables him to see even closer than the emmetrope.—(J. M. B.)

The non-operative treatment of myopia gravis. Koster, (*Zeitschrift f. Aug.*, 34, p. 215), sets forth his standpoint as to full correction of myopia. In his opinion full correction does not arrest the progression of myopia, but if full correction is tolerated by a patient, his case does not belong to the grave forms of myopia. The acceptance of full correction by a high myopic apparently depends upon the shape of his fundus, i. e., whether the whole surface of the fundus is more regularly ectatic or whether there is a large, more local posterior staphyloma at the macular region. In the first case the retinal image of the outer world is, after full correction, sharply-defined in a greater extent, in the second case the image at the macula is well-defined, but not that on its surroundings, and, for looking around, this indirect vision is of much greater importance. In such cases the peripheral parts of the retina are by full correction overcorrected, so that the patient commences to accommodate, in order to neutralize the artificial hypermetropia. That this actually occurs transpires from the fact that he soon feels a marked accommodative asthenopia and that he sees the objects considerably smaller, for the retinal image is actually smaller than normally in accommodative correction of too strong glasses. Furthermore there is no doubt that myopia is unfavorably influenced by constant accommodation. Only if full correction prevents the patient from blinking and thus pressing his eyes by the lids, as this frequently happens in wearing weaker glasses, it can be regarded as a remedy.

In the treatment of grave myopia one must from the start remember that it is not a simple error of refraction, but due to an insidious sclero-chorio-retinitis, the healing of which must be attempted, and as early as possible. For that purpose Koster gives small doses of iodin and

mercury preparations continued for years, viz., 14 days 0.5 iodide of potash, and 14 days from 0.025 to 0.050 hydrargyr. protoioduret., and so on, until marked improvement is noticeable. Near-work is not forbidden, but strain of accommodation avoided. Full correction is given for the school, for the street none, or weaker, glasses which are also used at home for reading, avoiding as much as possible convergence by doing near-work at 25 cm. In some cases an atropin cure is instituted during the winter months.

The best results are promised by radiation therapy, which Koster applies with radium bromide 0.004 or mesothorium in a glass globule at the end of a glass tube. With this the eyeball is stroked from the fornix of the lower and upper lids to the corneal limbus. It is disinfected in 5 per cent. carbolic acid or soap and alcohol. Each eye is exposed to the radiation in sittings of one hour with an interval of one week for five hours altogether. Sometimes it is followed by transient catarrhal secretion which must be treated. The lid border must not be exposed, as the skin does not bear radiation as well as the mucous membrane. The direct result of radiation is improvement of vision and healing of chorio-retinitis. Koster uses radiation also in the stage of degeneration: intense opacities of the vitreous, detachment of the retina, complicated cataract.

The article by Pollock, of Glasgow (*Glasgow Medical Journal*, October, 1916), on the reduction of myopia in children of school age, is of interest. One must hope that other ophthalmologists will have equally good results. The treatment is that by prolonged use of atropin, associated with removal from school, or, at any rate, with complete cessation of near-work. Pollock is fortunate in having to deal with the first School Board in Scotland to introduce the myopia class, namely, the School Board of Govan. The author says that his work in connection with the treatment of myopia began about six years ago with the extension of the use of atropin for testing the refraction. "It is," he says, "common knowledge that after a week of atropin the myopia is about a dioptre less than prior to using the atropin. This change has always been regarded as due to the relaxation of the accommodation, and accordingly no further reduction in the myopia was thought to be possible by continuing the mydriasis. My reason in the first instance for an extended use of atropin was to prevent the patient from doing near-work, and thus to give the eyes a more thorough rest; and also, if possible, to prevent a further increase in the myopia. I found, however, that in certain cases after two or three months of treatment the myopia not only stopped increasing, but actually showed a decrease. This induced me to persevere for much

more prolonged periods, and the result has been most satisfactory."

It is, of course, true that a great many ophthalmic surgeons must have employed fairly prolonged atropinization in cases of myopia, but, so far as the reviewer is aware, no one has ever published a series of cases showing a reduction of myopia following the use of this or of any other drug, in the least comparable to this series. The cases are four in number. The details follow:—

(1) A girl, aged 7 years, showed by retinoscopy after a week of atropin 11 and 9 D., in the vertical and horizontal meridians respectively, in each eye. After two months the retinoscopy was right eye 8 and 6 D., left eye 9 and 7 D. One month later, each eye was 7.5 and 6 D. Six months later, the right eye was 6 and 4.5 D., the left 6 and 4 D. Two months later, each eye had 6.5 and 4.5 D. This was the last measurement, on 28th October, 1914. Reduction 4.5 D. in ten months.

(2) A girl, aged 9 years, showed, after a week of atropin, 18 and 16 D. in each eye. Seven months later the right eye had 14 and 10 D., the left 13 and 9 D. Last examination September, 1914. Reduction 4 D. and 5 D. in R. E. and L. E.

(3) A boy, aged 11 years, after a week of atropin, showed 11 and 6 D. in the right eye, and 7 and 2 D. in the left. Three months later, the refraction was 8 and 4 D. in the right, and 6 and 1 D. in the left. Last examination May, 1914. Reduction 3 D. and 1 D. in R. E. and L. E. respectively, in three months.

(4) A girl, aged 9 years, presented, after a week of atropin, 13 and 12 D. in the right eye and 12 and 11 D. in the left. In three months, the right eye gave 10 and 8 D., the left 9 and 8 D. Last examination February, 1915. Reduction 3 D. in each eye in three months.

Pollock states that he has also obtained a reduction of 3 or 4 D. in cases of low myopia and that some of these have become converted into low hypermetropia. Relapses have occurred in some cases during the summer months when the school eye clinics are closed, and treatment was not carried out.

These are the main facts stated by the author, but he also refers to details of constitutional treatment, to atropin poisoning and atropin dermatitis, and to the well-known difficulty in getting near-work really suppressed. The recently instituted myope class has, however, justified all his expectations.

Can the development of myopia be arrested and its degenerative changes prevented?

Sidler-Huguenin, of Zurich (*Archives of Ophthalmology*, Vol. XLV, No. 6, November, 1916), propounds this question. As his answer is an unqualified negative, and as it is based on very painstaking work, it

cannot be lightly brushed aside, despite the fact that his conclusions are little short of revolutionary.

By the aid of carefully adjusted radiographs, he has satisfied himself that there is no close relationship between the contents of the orbit on one side and the refraction of the eye on the same side; he consequently rejects Stilling's theory. He next considers a series of 150 anisometropes, each of whom practically used only one eye. These patients gradually became more and more myopic in the worse eye, which he states they did not use. From this he deduces that "the use of the eye has nothing to do with the degree or the deleterious consequences of a near-sighted eye." He quotes Steiger in support of his position. Is it a valid argument that because an eye becomes more myopic when its fellow is working, it would equally become more myopic, if both eyes were laid aside from work? In other words, does an eye ever really rest whilst its fellow is working? The answer is almost certainly in the negative to both questions. In the 150 cases quoted there was evidence of heredity of myopia in 18 only. Yet the author says that "we must consider heredity as the most frequent etiological factor in the development of myopia."

In 4,000 myopic patients the author found disease of the macula in 218 eyes, and of these 49 had a myopia of less than 10 D. This corresponds with Schweizer's results in Haab's clinic. There, in 5,000 myopic eyes, 265 showed macular disease, and in 44 of them the myopia was under 10 D. In the 150 anisometropic cases already quoted, corneal changes were present in 78 eyes, whilst in the 4,000 myopes corneal maculæ were present in 187. The writer is inclined to agree with Meyerhof and others, that the corneal opacity is the cause of the development of the myopia, or, at least, that there is an association between opacity of the cornea or lens and myopia. He founds this view largely on the fact that in his series of cases a hereditary history of myopia is present in only one of the 78 eyes which showed corneal maculæ. He confesses himself at a loss to explain the causative relationship which he accepts. He suggests that in highly anisometropic eyes, the retina and choroid degenerate rapidly on account of lack of function, but his arguments fail to carry conviction.

He next has something trenchant to say of the bad results which follow the removal of the lens for the relief of high myopia. Again, his view that the use of the myopic eye is probably more favorable than non-use, is based on arguments that will provoke a challenge in a good many minds.

Some stress is laid on the opinions expressed by intelligent patients that a general treatment of their myopia had not affected the course

of the eye condition. It may, however, be questioned whether such evidence is of any value whatever. When the writer goes on to say that the usual directions which we give these myopic patients have but little effect, and, again, that myopia gradually increases, irrespective of external influences, to a degree which is dependent upon hereditary factors, one cannot but feel that such fatalism is in excess of what the arguments justify, and that to follow him in practice would be to set back the clock of progress.

On the strength of some very interesting figures, the author has come to the conclusion that "myopia may remain stationary just as well with under-correction as with full-correction," and again, "that full correction is not always capable of preventing the myopia from progressing."

It must be admitted that the writer has had a large clinical material, and has made much use of it, but the pessimism which he manifests towards one and all of the accepted means for the control of myopia will fail to appeal to a great many surgeons. To say that myopia is "a congenital evil which can only be influenced by the proper selection of individuals for marriage," is, from the point of view of practical results, a mere waste of breath. The article is interesting and stimulating; it is the expression of the thoughts of a man who dares to leave the beaten path, and any criticism should therefore be offered in a spirit of reluctance and respect. It is certainly a paper which every thinking ophthalmologist should read.—(R. H. Elliot.)

A suggestion as to the causes of myopia. Arthur Wood (*Ophthalmoscope*, July, 1916), puts forward the suggestion that the difference in the ciliary muscles of the myope and the hypermetrope is the cause of myopia, and that this difference is transmitted as an hereditary defect.

The ciliary muscle is composed of two parts, the outer meridional, Brücke's muscle, and the inner, Müller's muscle. Both are made up of unstriped fibres, the former more developed in myopic eyes and the latter more in hypermetropic eyes.

Müller's muscle constitutes about one-tenth of the ciliary muscle in the emmetropic eye, one-third in the hypermetropic eye, whilst in the myopic eye it is deficient or entirely absent. This difference in the condition of Müller's muscle is present at birth.

Contraction of the longitudinal fibers of the ciliary muscles exerts a suctional force upon the fluid in the space of Fontana, so that there is a stream flowing from the anterior chamber into the suprachoroidal spaces during the act of accommodation. In the myope cessation of accommodation causes the pumping action to become less and less. In

those eyes possessing the circular bundle, its action during accommodation is to drag the ciliary body inwards, thus widening the angle of the anterior chamber, and at the same time it will cause the alveoli in the pectinate ligament to become more spherical, thereby allowing more fluid to flow through. In the myope, where this bundle is deficient, this action is correspondingly less and less until it is nil in the case of those eyes where it is entirely absent. Not only is there absence of these functions, but there is no counteraction of the effect produced by the radial and longitudinal fibers when they pull the ciliary body forward and outward, thus lessening the angle of the anterior chamber.

The action of the circular fibers also is that of a pump during the contraction and relaxation necessitated by the act of accommodation.

Since there seems to be a general agreement amongst observers that the difference in structure of the muscle is present at birth, it may be taken that it is not the result of disease, of mechanical pressure, or disuse, but due to hereditary transmission of the defect from parent to child.

Domec urged the use of pressure massage, used in combination with miotics and the wearing of fully correcting glasses, as a means of arresting the development of myopia. The explanation offered was that the aqueous, driven into the sinuses by the slow pressure, dilates the natural passages, so that a larger quantity of intraocular fluid is excreted each time than usual. During the treatment the zonule becomes more elastic and the ciliary muscle stronger. The writer considers this explanation to be the key to the question as to how myopia becomes stationary.

The theory that myopia is due to close work aggravated by town life and badly-lighted rooms is gradually giving ground before statistics. The figures given by Arnold Lawson are quoted, where in the Aldenham and St. Jude's schools the percentage of myopia was actually five per cent. higher in the better lighted and ventilated school.

In the case of monocular myopia, the sound eye has a ciliary muscle, with Müller's bundle properly developed, the myopic eye is deficient in Müller's bundle, and as a consequence there is not the same machinery for promoting the normal flow of aqueous. Here there is no need to invoke causes which must act equally on both eyes to explain the disease being present in one eye only.

A case of twins is mentioned. They were of the same sex, and almost of similar appearance, and are evidently the product of one ovum. They have nearly the same amount of myopia, and the grounds of the fundus are exactly alike. This is easily explainable by the theory

that the muscles were alike and that in them the circular fibers were of the same volume.

Racial myopia has long been a subject of discussion, especially from the point of occupation. The writer suggests that it has far more significance when approached from the hereditary side, and is more satisfactorily explained by a congenital defect transmitted from parent to child.—(W. R. Parker.)

High myopia. A. Hugh Thompson, of London (*Proceedings Royal Society of Medicine: Section of Ophthalmology,* December, 1915), gives the late operative results obtained in 15 eyes (14 patients) after periods of from 5 to 15 years. These results are summarized in the table given below.

TABLE I.

Name	Sex	Age at time of first operation	Diopters of myopia	Best vision with a glass before operation	Number of years from first operation, with latest date seen	Best vision without glass at latest testing	Best vision with glass at latest testing	Remarks
A. L.	F.	17	—22	$\frac{6}{60}$	6 to 1911	$\frac{6}{60}$	$\frac{6}{18}$	—
R. E.	F	17	—17	$\frac{6}{18}$	9 to 1913	$\frac{6}{12}$	$\frac{6}{12}$	—
R. A.	F.	25	—16 5	$\frac{6}{24}$	10 to 1914	$\frac{6}{18}$	$\frac{6}{12}$	(1914) macular changes in unoperated eye; hæmoptysis, aged 35.
R. B.	F	16	—16 5 (left eye)	$\frac{6}{18}$ (2 let)	8 to 1912	$\frac{6}{24}$	$\frac{6}{18}$	—
		19	—14·5 (right eye)	$\frac{6}{24}$ (2 let)	5 to 1912	$\frac{6}{24}$	$\frac{6}{18}$	—
I C	F	9	—16	$\frac{6}{36}$	8 to 1914	$\frac{6}{12}$(2 let)	$\frac{6}{12}$	Mother of the patient a high myope with macular degeneration
L. F	F.	6	—16	Too young to test	7 to 1915	$\frac{6}{24}$	$\frac{6}{12}$	—
S P.	F	17	—19	$\frac{6}{18}$ (2 let)	7 to 1915	$\frac{6}{18}$	$\frac{6}{12}$	—
W. W.	M.	22	—20	$\frac{6}{60}$	5 to 1915	$\frac{6}{18}$	$\frac{6}{18}$	—
M T	F	22	—16	$\frac{6}{18}$	8 to 1915	$\frac{6}{12}$(2 let)	$\frac{6}{12}$	Macular hæmorrhage eight months after operation, this cleared up, leaving no trace

The table shows that ten eyes possess, after an average period of eight years, materially better vision than they had before operation, and that nine out of ten of these eyes obtained vision of 6/24, 6/18, or 6/12, without any glass.

The second table shows that in five instances the eyes have gone more or less wrong after enjoying good sight after periods varying up to ten years. The disaster in three out of the five cases was due to macular

degeneration. One of the other patients suffered from irido-cyclitis, associated with pyorrhea alveolaris, and a pupillary membrane re-formed each time it was needled. The bad result in the other patient was due to uveitis, but whether that was connected in any way with the operation performed six years before, Thompson is not prepared to say.

It is noteworthy that among the unfortunate cases in Thompson's series there is not one of failure due to detached retina. He feels doubtful whether a highly myopic eye is more subject to detachment

TABLE II.

Name	Sex	Age at time of first operation	Diopters of myopia	Best vision with a glass before operation	Number of years from first operation, with latest date seen	Best vision after operation	Duration	Latest test of vision	Cause of bad vision and remarks
L. B	F	6	—18	$\frac{6}{60}$	15 to 1915	$\frac{6}{18}$	10 years	$\frac{6}{36}$	Macular hemorrhage and degeneration in both eyes
M M	F	12	—16	$\frac{6}{36}$	11 to 1915	$\frac{6}{18}$	6 years	$\frac{6}{60}$	Choroiditis, an attack of cyclitis six years after operation, which cleared up
D H.	F	15	—17 5	$\frac{6}{60}$	8 to 1913	$\frac{6}{18}$	Uncertain	$\frac{6}{60}$	Macular degeneration
A B.	M.	18	—20	$\frac{6}{18}$ (1 let)	7 to 1914	$\frac{6}{18}$	5 years	P L	Macular degeneration; second eye also affected with macular degeneration, but vision — 21 = $\frac{6}{24}$
R. J.	F.	21	—18	$\frac{6}{24}$	5 to 1913	$\frac{6}{18}$	4 years	$\frac{6}{60}$	Iritic membrane; pyorrhea alveolaris

after operation than it was before. He adduces figures which go to bear out this view, that the surgical treatment of high myopia does not counteract the tendency of the long axis of the eyeball to increase.

A few other points brought out by Thompson may be glanced at.—The degree of myopia most suitable for operation is anything between 16 D. and 22 D. In the case of young children (in whom the condition is likely to be progressive), however, he would place the limit at 14 D. He would not operate upon an eye with much choroiditis, and especially not upon one the macular region of which was affected by degenerative changes. As to technique, the author freely needles the capsule of the lens. On an average, the total number of operations required from start to finish has been between three and four.—(Sydney Stephenson.) See **Myopia, High.**

Myopia, Apparent. Myopia produced by a tonic contraction of the ciliary muscle in an eye which is anatomically emmetropic or hypermetropic.

Myopia, Benign. Myopia not accompanied by ocular disease.

Myopia, Curvature. Myopia due to too great curvature of the cornea and lens.

Myopia, High. An excessive degree of axial myopia. This subject is treated under **Refraction** and **Myopia**. See, also, p. 4022, Vol. VI of this *Encyclopedia*.

The operative treatment of high myopia. The late results of this procedure are discussed by A. Hugh Thompson (*Med. Press*, November 17, 1915). The author alluded to notes which he had published five years ago giving an experience with *20 myopic eyes which had been needled.* He relates his further experience of such of those cases as he had been able to keep in touch with. During the last five years, in common with many others, he had been chary about recommending this operation, though he still maintained that in carefully selected cases the treatment was a good one. As one could not be certain about the future of these eyes, the procedure should not be pressed upon any patient, for one could not promise cure, and the eye was left just as liable as ever to those destructive processes which attacked highly myopic eyes. The degree most suitable for operation was 16 to 22 diopters. In young children, whose myopia was certainly progressive, a limit of 14 D. might well be assigned. With a myopic of more than 22 D. the chance of the eye remaining free from destructive processes was small. His method had been a free needling of the lens capsule, after which it was necessary to watch the patient carefully day by day, and in the event of a rise of tension let out the lens matter by means of a keratome incision through the cornea. Should a secondary membrane form some years after, this must be needled. He had been able to follow up 14 cases, during periods of five to fifteen years. Only one patient was operated upon in both eyes, and he did not think the advantage justified the double operation. In all the 15 eyes, the result of the operation was good, and the subsequent results he tabulated in detail. Two-thirds of the cases, after an average period of eight years, had materially better vision than before the operation. In not one of them had he to deal with a detachment of the retina as a sequela of the operation, though it was well known to occur occasionally. He did not think the operative treatment of high myopia tended to counteract the increase in the long axis of the eyeball, though obviously the removal of the lens had the effect of diminishing the result of the lengthening of the axis of the eyeball on the refraction by about one-half. See **Myopia.**

Myopia, Macula in. See **Macula, Myopic.**

Myopia, Progressive. The malignant form of the disease in which the

anteroposterior axis tends to lengthen and the eyeball to enlarge. Among the other authorities Koster (*Jour. Am. Med. Assocn.*, Aug. 12, 1916) agrees with Donders that there is usually disease where there is myopia. This is beyond question with severe progressive myopia, and the clinical course and effects of treatment reveal the ocular affection as a primary infectious chronic chorioretinitis. Any degeneration observed is of secondary nature. In treatment the patient and parents must be warned to refrain from taxing the eyes beyond what is strictly necessary, and all exercises, games, etc., must be avoided that are liable to induce congestion in the head. General treatment is important; for this he alternates mercury and potassium iodid for two weeks each, keeping this up unmodified if the myopia continues to progress by the end of six months but the vision has shown no impairment. If there is any decline in vision while the myopia progresses, he keeps the patient in bed for six weeks with daily inunction of 3 gm. of mercury, supplemented by radium treatment of each eye for five hours at weekly intervals. If there is much hyperemia or signs of a tendency to chronic cyclitis, he gives a course of atropin. The eyes are given complete rest therewith. If there are any contraindications to mercury, he gives a course of salicylates instead, with iron and a strengthening diet.

After such a course of treatment the eyes can be used systematically a little and the further development of the case watched. He deplores that he can so seldom induce patients to take this regular course of treatment. The time required, the expense and the dread of mercury combine to make patient and parents shrink from it. Sometimes all he can get consent for is a brief course of radium treatment and protracted medication with small doses of mercury, the salicylates, iodids or iron, but he insists that these must be kept up for years.

Progressive myopia with detachment of the retina or other serious complication he treats in the same way, aiming to retain vision as good as possible in the comparatively sound eye. He declares further that even a slight degree of accommodation is harmful in time for eyes with progressive myopia. The hyperemia induced by accommodation aggravates the infectious process.

He has had many years of experience with treatment based on the above premises. Some patients with myopia of 20 and more D. have had it arrested at this point, so that the myopia was retarded so that the progress grew very slow and vision was less impaired than in the untreated. He adds that the results of operative treatment have proved so unsatisfactory in the long run that operative measures now have been generally abandoned. See **Myopia.**

Myopiasis. An old and obsolete synonym for myopia.

Myopic. Affected with myopia; brachymetropic.

Myopiosis. Myopia. Short-sightedness; that condition of the eyeball in which, owing either to the antero-posterior axis of the eye being too long or to the refracting power of the dioptric media being too high.

Myoplasty. Plastic surgery on muscle.

Myopodiorthoticon, Berthold's. A name given by the inventor (*Das Myopodiorthoticon*, 1840) to a certain form of desk by means of which the myope was compelled to hold his book at the greatest possible distance from his head that would permit of reading. This distance was gradually increased. See p. 943, Vol. II, of this *Encyclopedia*.

Myopodiorthoter. Myoporthon. Myopodiorthoticon. Old terms for an apparatus invented by Berthold for the correction of myopia.

Myoporthosis. (Obsolete.) The correction of myopia.

Myopresbyte. Shortsighted and presbyopic.

Myops. A person affected with myopia.

Myopsia. That condition of the eye in which muscæ volitantes are perceived.

Myopsid. Having the cornea clouded; opposed to oigopsid.

Myopsis. A condition of the eyes in which black specks are seen passing before them; muscæ volitantes.

Myopy. A form of the word myopia.

Myosalgia. Muscular pain.

Myoscope. An instrument for the observation of muscular contractions.

Myoseism. Jerky, irregular muscular contractions.

Myosis. Proper spelling, *miosis*. Contraction of the pupil; caused by direct irritation of the motor filament supplying the sphincter (often by drugs) by reflex irritation from the fifth nerve, or by paralysis of the vaso-constrictor nerve fibres of the iris from a lesion of the nerve-centers or of the cervical sympathetic. See **Pupil in health and disease.**

Myositic. (Myotic.) Properly *miositic* and *miotic*. (a) Pertaining to or causing miosis. (b) A drug which induces miosis.

Myositis, External ocular. True inflammation of the extrinsic eye muscles is a very rare condition, probably always associated with tenonitis or orbital cellulitis. It may result, according to some observers, from gout or rheumatism.

The treatment resolves itself chiefly into the therapy of the underlying cause or associated disease. Hot fomentations, leeching, subconjunctival injections of acoin in oil will relieve pain and local tenderness as well as hasten resolution of the inflammation.

Myosotis palustris. Common (or true) Forget-me-not, Water Myosote, or Mouse-ear. This blue-flowered perennial plant grows in marshes;

it has mucilaginous properties, and the macerated leaves were formerly used as a cataplasm in ophthalmia.

Myospasia. Clonic contraction of muscle; paramyoclonus.

Myospasm. Spasm of a muscle.

Myotasis. Stretching of a muscle.

Myotenotomy. Surgical division of the tendon of a muscle.

Myotome. An instrument for performing myotomy.

Myotomia intra-ocularis. SCLEROCYCLOTOMY. Hancock's operation for the relief of glaucoma. See, also, p. 5693, Vol. VIII of this *Encyclopedia.*

Myotonia. Tonic spasm of a muscle. Myotonia congenita, or Thomsen's disease, is a rare affection that sometimes attacks the ocular muscles. It is seen in different generations of neurotic families, and is either a disease of the muscles themselves or a trophoneurosis. There is at times a disorder of the muscular apparatus of the eyes. The lids may partake of the general muscular stiffness. Amblyopia of a temporary character has also been observed.

Myotonia atrophica. Wasting of the extrinsic ocular muscles designated by this title and associated with cataract is described at length by A. W. Ormond (*Trans. Oph. Soc. U. K.*, p. 214, 1911).

Myotonic convergence. This most unusual condition is discussed by Magitot (*Ann. d'Oculistique,* April, 1911). A woman, aged 57 years, had mydriasis and irregularity of the left pupil. The reaction to light was absent in the left pupil and normal in the right. On convergence the following phenomena were observed: the right pupil contracted and then resumed its original condition; the left pupil contracted more slowly than the right, but continued doing so until it became punctiform, in which condition it remained for ten to fifteen seconds, after which it dilated slowly, reaching its original size in about one and a half minutes. The patient volunteered the information that on waking in the morning, her left pupil was smaller than the right, and remained so for some time. The eyes were otherwise normal, apart from some patches of anterior chorio-retinitis in the right, and they reached full vision with correction of 2.5 D. of myopia.

Morax details a case in the *Encyclopédie Française d'Ophtalmologie,* in which the Argyll Robertson pupil was bilateral, but the myosis occurred in the left eye only, and refers to other recorded cases. He discusses the situations suggested for the anatomical lesions underlying the conditions (and also the Argyll Robertson pupil phenomenon), and comes to the conclusion that, in all probability, they are located in the ciliary ganglion rather than in the mesencephalic cilio-motor

centre, the roots of the dorsal nerves, the inhibitory centre in the floor of the fourth ventricle, or the iris itself.

Myotonic pupil movement. A name given by Saenger to the pupil, immovable to light, that reacts to convergence and remains contracted for several minutes after the act of convergence.

Myotonometer. An instrument for measuring muscular tonus, or contractile power.

Myriorama. A series of interchangeable pieces bearing partial pictures, which can be arranged all together in different ways to form a variety of harmonious designs or landscape views.

Myrioscope. A form of kaleidoscope in which the object examined consists of a portion of a length of embroidered work which traverses the bottom of the box.

Myrocollyrium. (L.) An ancient term for an ointment-like collyrium.

Myrrh. Gum-resin myrrh. A resinous gum from *Commiphora myrrha.* It contains a volatile oil, glucoside, myrrhin, etc., and acts locally as an astringent.

The tincture is the preparation commonly used as a local application in eye diseases, in the proportion of 1 to 5 per cent. In this, as in other spiritous combinations, it must be remembered that the alcohol plays an important part. Percy Friedenberg uses the following mixture as an astringent for conjunctival catarrh: Tinct. myrrhæ, 1.00; aquæ rosæ, 6.00; sat. sol. acid. boric., 15.00.

In ancient Greco-Roman times, myrrh was in high repute as a remedy for trachoma, for ulcers and scars of the cornea, and for affections of the eye in general if accompanied by pain. The resin was the part employed. It was used in the form of a powder, or mixed with honey, or as a resin-soot.—(T. H. S.)

Mytilotoxin. A volatile alkaloid (not a ptomain), $C_6H_{15}NO_2$, found especially in the liver, in poisonous mussels; supposed to be the toxic principle. It is like curare in its action, producing head-drop, dyspnea, convulsions, and paralysis.

Myrtle. *Myrthus communis.* According to Pliny and Dioscorides, the leaves and the fruit of the myrtle were both employed in ancient Greco-Roman times as a remedy for pterygium, for ægilops, and for any acute affection of the eye.—(T. H. S.)

Myxangitis. Inflammation of the ducts of mucous glands.

Myxedema. Myxœdema. A trophoneurotic condition characterized by general dropsy-like swelling, especially of the face and hands, caused by the presence of mucous fluid in the subcutaneous tissues. The swelling is hard and puffy and does not pit on pressure. The disease is associated with atrophy of the thyroid gland, and is apparently

due to excess of mucin in the system. It is marked by dullness of mental faculties, sluggishness of movement, unsteadiness of gait, and thick speech. (Dorland.)

The *ocular signs of myxedema* are generally external, although intra-ocular changes have been noted.

In addition to the changes in the skin of the lids, loss of the eyebrows, tremor of the orbicularis palpebrarum, other ocular disorders have been noted, though the etiological relationship is by no means certain. To deficiency of the thyroid internal secretion, Demets (*Soc. Française d'Opht.*, May, 1908) ascribes such congenital anomalies as anophthalmos, aniridia, albinism, zonular cataract, and various colobomas, besides retinitis pigmentosa and congenital strabismus. During the period of growth he believes it causes keratitis, neuroretinitis, uveitis, vitreous hemorrhage, and phlyctenular disease. In the adult it produces retinal hemorrhage, arterio-sclerosis, optic atrophy, and senile cataract.

In an analysis of fourteen cases reported by different observers, Derby (*Jour. A. M. A.*, Sept. 21, 1912) states that the most marked change is found to be a low-grade *optic neuritis*, ranging from this condition to an atrophy without definite signs of a previous inflammation. The fields of vision present points of striking interest. In seven of the cases one or both eyes presented evidence of a temporal hemianopsia, pointing almost inevitably to the pressure on the optic chiasm by an hypertrophy or new-growth of the hypophysis. There is apparently a close relationship between the hypophysis and the thyroid. Histologically the thyroid gland and the anterior lobe of the hypophysis develop from the same embryonic structures, and show a close histological similarity. Furthermore, in all but exceptional cases of acromegaly the colloid degeneration, with or without cyst formation, which is found in the hypophysis, is also present in the thyroid. Conversely, a number of observers have found in myxedema, cretinism and similar conditions, enlargement of the sella turcica and disease of the hypophysis. Wordsworth, in 1884, published a case of myxedema and double optic atrophy, but subsequently admitted that the case was probably one of acromegaly.

Clinically, the signs of acromegaly may be combined so closely with those of myxedema that it is hard to decide which set of symptoms is preponderant. Cases are occasionally found which present a combined picture of exophthalmic goitre and acromegaly; and signs of exophthalmic goitre, myxedema and hypophyseal enlargement may be present in the same patient at different times.

The good results following treatment with thyroid extract show

the close relationship this condition bears to affections of the eye. See, also, **Cretinism**; as well as **Acromegaly**.

Myxofibroma. Myxoma blended with fibroma. Parsons believes that the so-called myxofibromata affecting the eye are really only soft, degenerated (but pure) fibromata.

Myxolipoma. A lipoma the subject of myxomatous degeneration. Ocular tumors of the sort are excessively rare, although Wingenroth (*Archiv f. Ophthalm.*, page 2, 1900) has described a case in which all four eyelids were involved.

Myxoma, Ocular. This form of tumor, made up of mucous tissue forms a soft, translucent growth composed of variously shaped cells of connective tissue and capillary vessels encased in a jelly-like matrix. Sometimes they contain cavities (cystic-myxoma). According to the various tissue elements which make up these growths, they are called enchondromatous myxoma, myxoma fibrosum, myxoma sarcomatosum, etc. These tumors are of infrequent occurrence about the eye, though occasionally seen in one of the mixed forms. Rumschewitsch (*Klin. Monatsbl. f. Augenh.*, vol. 28, 1890) described a myxoma of the upper lid, but it was probably an edematous fibroma. When occurring on the conjunctiva, it is usually as a polypus. These polypoid growths sometimes follow suppurating wounds of the cornea or a perforating corneal ulcer. They are reddish, pedunculated, smooth, globular masses, sometimes as large as a cherry, and should be removed by excision. Myxomata have been found, but with extreme rarity, in the lachrymal gland and in the optic nerve.

Myxorrhea. A name given to blennorrhea.

Myxosarcoma. Sarcoma that has undergone myxomatous degeneration. Neoplasms of this description are reported (but rarely) as attacking the optic nerve, orbital contents and lachrymal gland.

Segi's case (*Klin. Monatsbl. f. Augenheilkunde*, May, 1913) was in a female child, seven years old, of rickety constitution. There had been increasing prominence of the left eye for two years. The left eye was markedly prominent and rotated down and out. There was great limitation of movement. There was complete blindness of the eye, and ophthalmoscopic examination showed optic neuritis subsiding into atrophy. The right optic disc also showed atrophic pallor. Fingers could be counted at four metres, and there was contraction of the field of vision. The contents of the left orbit were removed, and showed a large egg-shaped tumor embracing the optic nerve right up to its entry into the globe. It was found to be a fibro-myxo-sarcoma of the nerve taking origin from the inner sheath and the perineurium.

From a review of the literature in general, and the work of Salzmann

in particular, it appears that myxosarcoma does not possess the power of unlimited growth. It may, therefore, be placed among the benign tumors, the prognosis after removal of which is good. Since these form the majority of tumors of the optic nerve, the prognosis after removal of optic nerve tumors, in general, may be said to be favorable. The exceptions are chiefly those of the dural sheath, which are apt to be sarcomata or endotheliomata of great malignancy.

N

n. The symbol for index of refraction; also, a symbol for *normal.*

Na. Symbol for sodium.

Nabit. Pulverized white sugar; formerly used in diseases of the eye.

Nacarat. A light red or scarlet color.

Nachbild. (G.) An impression of an object upon the retina which remains for a certain time after the light is withdrawn.

Nachblutung. (G.) Secondary hemorrhage.

Nachempfindung. (G.) The perception of a sensory impression after the cause producing the impression has been removed; the conscious reception of an after-sensation. The persistence of a sensory impression after the sensory stimulus which gives rise to it has ceased to act.

Nachstar. (G.) Secondary cataract.

Nachtblindheit. (G.) Night blindness.

Nachtschatten. (G.) Atropa belladonna.

Nachtsehen. (G.) NACHTSICHTIGKEIT. (G.) Day-blindness; a form of retinal hyperesthesia in which there is distinct vision only at night or by a feeble illumination; said to be caused by long exposure to glistening surfaces. It also occurs in tobacco amblyopia and in central opacities of the cornea or lens, because vision is then better when the pupil is dilated.

Nadel. (G.) A needle.

Nadeldose. (G.) Needle case.

Nadelhalter. (G.) A needle-holder.

Nadel zur Augennaht. (G.) Armed needle used in ophthalmic operations.

Nævus conjunctivæ. See **Nævus, Ocular.**

Nævus, Ocular. Angioma of the skin and conjunctiva is rounded or irregular in shape and size, and bright-red, violaceous, or blue in color. These tumors are very vascular, being composed essentially of dilated or hypertrophied blood-vessels. They occur not infrequently about the eyelids, on the bulbar conjunctiva, and on the surface of the iris. They are usually pigmented, rarely non-pigmented. The pigmented variety is usually small, slightly elevated, and when situated on the skin, hairy. The vascular, non-pigmented variety is slightly

elevated and presents a bluish appearance ("strawberry-patch"). The *nævus vinosus,* or the small, bright-red patch with radiating ("spider-leg") vessels also occurs. The so-called *nævus-flammeus,* or port-wine mark is the form which most frequently involves the integument of the lids and the sclera. Both the pigmented and non-pigmented types of nævi are benign, but both possess high potential capacity to become malignant.

The *nævus pigmentosus,* or pigmentary mole, is found on the eyelids, the upper lid being more frequently involved. It occurs singly or in numbers. They are smooth, warty, fatty and hairy, oval or circular in shape, and vary in size from that of a pin-head to a large tumor-like mass.

When occurring in the conjunctiva, the pigmented spots are flat, and are made up of groups of large cells of endothelial type-round or polygonal, flat, often with processes. The pigment is both intra- and inter-cellular, and consists of golden or brown granules of various sizes. The connective tissue cells may also be pigmented, and the epithelium over the spot also frequently contains pigment. When these spots start proliferating they form intensely malignant melanotic growths. The more typical nævi are slightly swollen and gelatinous-looking, and smooth. The epithelium is prolonged downward for a short distance in club-shaped expansions, which divide and form a net-work. In the spaces of this net-work are groups of smaller epitheloid cells—the so-called "nævus cells." They have, therefore, a sort of alveolar arrangement, and are separated from the epithelial cells and substantia propria by strands of fibrous tissue, which, however, forms no stroma between the cells except at the periphery of the alveoli. In the pigmented variety the pigment is present throughout, but especially on the surface, the epithelium also participating. The granules are brown and irregularly distributed; many of the spindle-shaped and stellate connective-tissue corpuscles are deeply pigmented, some being isolated, others forming bands. These have been called *chromatophores.* Some authors regard these nævus-cells as epiblastic, others as mesoblastic. Many look upon them as endothelial cells, others as offsprings of the chromatophores. When they become malignant they are named according to the views of their origin, as alveolar sarcoma, endothelioma, epithelioma, melanoma, etc. It is common to find cysts in these tumors, and the cystic development may be very pronounced (Parsons).

From extensive studies made on eleven cases of nævus of the conjunctiva, caruncle and plica semilunaris, Wolfrum (Graefe's *Archiv,* Vol. 71, part 2, 1909) concludes that the pigmentations which we find in the conjunctiva must in most cases be looked upon as nævi, since

besides the pigmentation in the epithelium, in the subconjunctival tissue too, there is found more or less pigmented cell aggregations, the epithelial origin of which can with careful searching in the earlier stages be proven in every instance. The capabilities of these cells to act histolytically and to wander, they share with the tumors, and must be considered as characteristics similar to those of the latter. Therefore tumors growing from these cell aggregations must be considered as carcinomata, yet not as carcinomata in the usual meaning of the word, since they develop mostly from basal epithelial cells and should therefore be designated as basal-cell carcinomata.

The non-pigmented variety of nævus is seen far less frequently than the pigmented type. A case was reported by Smyth (*Trans. Ophth. Soc., Unit. King.*, Vol. XXVI, p. 27, 1906) of an irregular, roughly crescent-shaped growth of the ocular conjunctiva encroaching on the upper part of the limbus. There was some doubt as to the true nature of the growth, but after its removal it proved to be a typical example of unpigmented nævus, made up of masses of "nævus-cells" as well as cells of epithelial type. Blood-vessels were very small and scanty within the tumor.

There have been comparatively few reported cases of unpigmented nævus on the cornea. Jaworski (*Klin. Monatsbl. f. Augenh.*, May-June, p. 572, 1911) described one in this location which exhibited characteristics typical of this form of nævus.

Pigmented nævi in the iris are not very uncommon. They are usually situated in the anterior limiting layer. Here the pigment granules may be so densely aggregated that the nuclei of the cells are hidden; the individual pigment granules are often very large. The surface of the iris may project forward at the site of the nævus, which frequently lies upon a bed of pigmented stroma-cells. The nævi are often situated near the pupillary edge of the iris. Fuchs regarded the cells as derived from the stroma, though he recognizes the existence of pigmented spots derived from the retinal pigment epithelium. The pigmented cells of the nævus may be round, in which case their resemblance to those of true nævus of the skin, conjunctiva, etc., is well marked. According to Parsons, two types of pigmented spots are met with in the iris: (1) aggregations of branched pigmented stroma-cells; (2) aggregations of pigmented cells derived from the retinal pigment epithelium.

Nævus vasculosus is a pathologic new formation, in fact an angioma, which so far has not been anatomically described, until Fuchs found it in seven cases. He assumes an augmentation of blood vessels and a proliferation of their walls, and believes they are developed from

capillaries which are present in an abnormally large number at a point especially near the sphincter, and by proliferation of their endothelium form a stroma in which lie the nævus vessels, probably from a congenital predisposition.

Since true nævi definitely seem to be formed by an alteration in the epithelial cells, we have to look upon them as a special kind of basal cell cancer. It is wisest, therefore, to remove every nævus as soon as it comes into our hands. For the larger ones, excision is indicated, and for the smaller, electrolysis is perhaps the best method. Ethylate of sodium has been employed in the treatment of nævi of the conjunctiva.

The dessication method has been used with success by Clark (*Jour. Amer. Med. Assn.*, July 1, 1916) in the removal of benign growths on the margins of the lids, and involving the palpebral conjunctiva. He believes this method is indicated both from a curative and a cosmetic standpoint. The same observer also recommends the use of filtered ultra-violet rays in the treatment of nævus flammeus (*Therapeutic Gazette,* May, 1916). The Kromayer modification of the Cooper-Hewitt mercury vapor generator is used, and the rays are filtered by means of quartz lenses. In "port-wine" nævi and allied lesions, when compression plus the blue quartz filter is used, thrombosis and an inflammatory reaction is produced in the capillaries comprising the nævus, of sufficient intensity to cause absorption, subsequent loss of function, and final obliteration. In treating nævi of the eyelids, care should be taken not to expose the cornea, or damage may be done. The eyes should be protected during all treatments, by goggles or other suitable covering. Nævi of the iris should be removed by making a broad iridectomy.—(C. P. S.)

Nævus pigmentosus. See **Nævus, Ocular.**

Nævus vasculosus. See **Nævus, Ocular**; also **Angioma.**

Nævus vinosus. See **Nævus, Ocular.**

Nafalan. A product almost identical with naftalan.

Nafis ad-din b. Zobeir. A famous Indo-Arabian oculist, who practised officially as ocular surgeon in the Hospital at Cairo, Egypt, for many years in the 12th and 13th centuries.—(T. H. S.)

Naftalan. A rectified petrolatum from Russian petroleum, containing about 3 per cent. of a hard soap. It is antiseptic, and is used as a vehicle in external medication.

Nagel, Albrecht. A celebrated German ophthalmologist, founder of the well-known *Ophthalmologische Jahresbericht,* and the first to show the relation between accommodation and convergence as expressed by the meter angle. See p. 473, Vol. I of this *Encyclopedia.*

Born in 1833 at Danzig, Germany, he studied medicine at Königsberg and Berlin, at the latter institution receiving his degree in 1855. Devoting himself to ophthalmology, he became extraordinary professor of that subject at Tübingen in 1867, and full professor in 1874, as well as Director of the University Ophthalmic Hospital. He founded the "*Jahresbericht*" in 1870 (it is still published under his name), and for many years he edited both this publication and the "*Mittheilungen aus der Ophthal. Klinik in Tübingen.*" He died July 22, 1895.

Among Nagel's more important writings are the following:

1. Das Sehen mit zwei augen, etc. (1861.)

2. Die Refractions-und Accommodations-Anomalien des Auges. (1866.)

3. Die Behandlung der Amaurosen und Amblyopien mit Strychnin. (1871.)—(T. H. S.)

Nagel's anomaloscope. See p. 499, Vol. I, and 5093, Vol. VII of this *Encyclopedia.*

Nagel, W. A well-known professor of physiology at Rostock, Germany, of importance to ophthalmologists because of his researches in connection with the physiology of vision, and especially with the action of light upon the retina. He was born in 1870 and died in 1911. See **Nagel's anomaloscope.**—(T. H. S.)

Nagib ad-din as-Samarqandi. See **As-Samarqandi.**

Nahepunkt. (G.) Near point.

Näherung. (G.) Convergence.

Nahrung. (G.) Aliment; food; nutriment.

Nahrungsmittelvergiftung. (G.) Poisoning by food products.

Nähseide. (G.) Suture or thread silk.

Naht. (G.) The procedure of stitching parts together, particularly the lips of a wound.

Naja tripudians. The systematic name of the Indian cobra whose deadly bite has caused blindness in those who have survived the poisonous attack.

Nanism, Ocular symptoms of. Brunier (*Annals of Oph.*, April, 1912) has directed attention to nanism or dwarfing due to decreased functioning of the anterior lobe of the pituitary body early or in infancy. This condition is also attended with atrophy of the external and internal genital organs and disturbances of vision. The visual disturbances are caused by optic nerve atrophy and present symptoms varying from bitemporal hemianopsia to complete blindness. The patients are infantile intellectually and complain of severe headaches, which are often accompanied by vomiting.

The case of a male, age 26, 1.25 meters in height, who presented

all the clinical signs of a tumor of the hypophysis (bilateral atrophy of the optic disk, temporal hemianopsia, headache, vomiting, enlargement of the sella turcica) is reported. The tumor in question developed very slowly and dated from infancy. This was proved by blindness of the right eye, which began at the age of 8. At this early age the tumor had already attained a size sufficient to cause compression of the optic nerve and resultant blindness of the right eye. The patient ceased growing at the age of 10; is a dwarf, in whom the juxto-epiphyseal cartilages still persist.

Nannoni, Angelo. A famous Italian surgeon, who paid considerable attention to diseases of the eye. Born in 1715 at Jussa, near Florence, he studied in Florence and Paris, and, returning to Florence, practised there until his death, in 1790.

His only ophthalmologic writing was entitled "Dissertazioni Chirurgiche, cioé della Fistola Lagrimale, delle Cataratte, dei Medicamenti Exsiccanti e Caustici" (Paris, 1748).—(T. H. S.)

Nanocephalia. NANOCEPHALY. Abnormal smallness of the head.

Nanophthalmia. Dwarfing or diminution of the size of the eyeball in those rare cases in which the organ is otherwise normal. Microphthalmia includes all cases of congenitally small eyes whether functionating or not.

Nanus. A dwarf.

Naphtha. See **Petrole.**

Naphthalin, Ocular symptoms from. A silvery, crystalline hydrocarbon, C_{10} H_8, from coal-tar oil. It is insoluble in cold water, but soluble in hot water, alcohol, ether, chloroform, and benzene. It is used as an antiseptic in the diarrhea of typhoid fever and locally in pruritus, scabies, etc. Dose, 2-10 gr. (0.133-0.66 gm.).

For the oculotoxic symptoms due to this poison, see **Cataract, Naphthalin,** p. 1564, Vol. III, of this *Encyclopedia;* also **Toxic amblyopia.**

Naphthol. See **Betanaphthol,** p. 945, Vol. II of this *Encyclopedia.*

When used for a considerable length of time, even externally, this drug not infrequently produces cataract and various alterations in the choroid and retina. See **Legal relations of ophthalmology,** in middle third of section.

Van der Hoeve (*Archiv. f. Ophthalm.,* p. 305, II, Vol. 85, 1913) has studied the action of naphthol on the eye, including the inunction of naphthol salve and subcutaneous injection of the drug in rabbits, and the observation of twenty human patients to whom the drug was administered clinically by inunction. The changes in rabbits' eyes included destruction of the retinal layer of rods and cones, and the formation

of lens opacities. In all the human subjects observed the fundus became hyperemic within two days, returning to normal on omission of the drug; but lens opacity was only discovered in one patient, appearing in the posterior cortex. Four litters of living rabbits whose mothers had been poisoned with naphthol during pregnancy all showed examples of congenital cataract.

Napropathy. A system of empirical medicine which attributes all diseases, including those of the eyes, to disorder in the ligaments and connective tissue.

Narbe. (G.) Scar or cicatrix.

Narbenectropium. (G.) Eversion of the lids due to the contraction of scars.

Narbenfibrom. (G.) Cicatrical fibroma.

Narbenflügelfell. (G.) Cicatricial pterygium.

Narcissus. *Narcissus pseudonarcissus.* According to Pliny the elder narcissus juice, mixed with mother's milk, was employed as a remedy for black eyes, epiphora and ocular pains of any sort or kind.—(T. H. S.)

Narcofin. A proprietary double salt of morphin and narcotin: used like morphin.

Narcosis. See **Anesthesia.**

Narcotile. An ethyl chloride and bromide (proprietary) mixture, advised by some in general anesthesia. See p. 4541, Vol. VI of this *Encyclopedia.*

Narcotin. A crystalline alkaloid, $C_{22}H_{23}NO_7$, derived from opium. It is antipyretic and tonic and has no narcotic powers whatever. It is, however, hypotic in from 0.25 to 1 grm. In full doses it has produced headache and mydriasis.

Nard. In ancient Greco-Roman times, a number of plants known as nard, or spikenard, were employed as therapeutic agents in various diseases of the eye. As a rule, the various kinds of nard were distinguished merely by the country of their origin; thus, Gaulic, Cretic, Italian, and Indian nard. Nard was often employed to promote the growth of cilia, and also for the cure of corneal ulcers. The oil of certain kinds of nard was also employed at times to increase the visual power.—(T. H. S.)

Nargol. An argentic compound with nucleinic acid, derived from yeast. It contains about ten per cent. of metallic silver, readily dissolves in water and is said to penetrate the tissues deeply and not to irritate mucous membranes.

Nargol is considered by some observers to be quite the equal of argyrol and protargol as a germicide. Like those agents it is non-

irritating and is used in about the same dosage (5 per cent.) for such cases as should be treated with silver salts. Some ophthalmologists prescribe it in the form of salve—5 to 10 per cent.—as a stimulant to slowly-healing corneal ulcers and in the chronic forms of blepharitis.

Nasal canthus. Inner canthus.

Nasal diplopia. Crossed diplopia.

Nasal diseases in ophthalmology. See p. 1810, Vol. III of this *Encyclopedia.*

Nasal duct. See, for the anatomy, physiology and pathology of this canal, p. 351, Vol. I, of this *Encyclopedia;* also sub-sections of the subject under **Lacrimal apparatus** (p. 6919, Vol. IX); and under **Cavities, Neighboring.**

Nasion. The middle point of the frontonasal suture.

Naso-ciliary. Pertaining to or connected with the nose and the ciliary body.

Nasolacrimal canal. See **Nasal duct.**

Naso-ocular. Pertaining to the nose and an eye jointly.

Natal boil or sore. A kind of sore, endemic chiefly in Asia and Africa, and marked by the development on the face of a papule which passes successively through the stages of tubercle, scab, and circumscribed ulcer. It is thought to be caused by a protozoan parasite, termed *Helcosoma tropicum,* or *Leishmania tropica* or *furunculosa.* The disease has received various names, according to the locality of its occurrence, as Aleppo boil, Delhi sore, Pendjeh sore, Natal boil, Biskra button, Lahore sore, etc., but the conditions occurring under the various names are practically one and the same disease. See p. 217, Vol. I of this *Encyclopedia.*

Natal ophthalmia. Congenital disease of the eye.

Natatorium conjunctivitis. See p. 3165, Vol. V, of this *Encyclopedia.*

Natrium. Sodium.

Natrium biboricum. See **Sodium borate.**

Natrium iodatum, P. G. See **Sodium iodide.**

Natrium salicylicum, P. G. See **Sodium salicylate.**

Natrium sulfuricum. See **Sodium sulphate.**

Nauscopy. The art of sighting ships at a great distance.

Nausea from ophthalmic causes. Apart from this symptom as an accompaniment of migraine and oculomuscular pareses (with diplopia) the commonest form of ocular nausea is that associated with car-sickness. See p. 1429, Vol. II of this *Encyclopedia.*

Naval, Don Juan. A Spanish ophthalmologist of the 18th century, who wrote, "*Tratado de la Ophtalmia y sus Especies*" (Madrid, 1796). Practically nothing else is known concerning him.—(T. H. S.)

Naval marksmanship and vision. See **Marksmanship, Ocular relations of,** p. 7599, Vol. X, of this *Encyclopedia.*

Navel, Ocular relations of the. Lewin and Guillery (*Die Wirkung der Gifte auf das Auge,* II, 89) include phlebitis of the umbilical veins as one of the possible sources of septic embolism of the eye.

Navelwort. *Cotyledon umbilicus.* According to Pliny the elder and Dioscorides, the juice of the navelwort was highly esteemed in Greco-Roman antiquity, as a strengthener of the sight and an all-round remedy for diseases and injuries of the eye.—(T. H. S.)

Near point. Punctum proximum. The nearest point (p) at which the finest print can be read. See **Amplitude of accommodation,** p. 329, Vol. I, of this *Encyclopedia.*

Near-sight. Short-sightedness; myopia.

Near-sighted. Short-sighted; affected with myopia.

Near-sightedness. The state of being near-sighted, usually employed as a synonym of myopia.

Nebenachse. (G.) Secondary axis.

Nebenapparate. (G.) Accessories.

Nebenchari. The greatest oculist of Egypt in the 6th century B. C. There is an interesting story about this man which has been preserved by Herodotus. Cambyses, son of Cyrus, king of Persia, finding that his mother, Kassandane, was blind, sent to Amasis, king of Egypt, beseeching him to dispatch to her aid the greatest Egyptian oculist, whoever that might be. Amasis sent to her Nebenchari.

This oculist, on arriving in Persia, found his royal patient afflicted with senile cataract. For some reason, however, he hesitated to perform an operation, until one day, happening to hear that his king, Amasis, had also gone blind from the same affection, and that he had been successfully operated on by Nebenchari's great rival, Pentammon, the timorous Nebenchari took heart, operated (by couching*) and restored to Kassandane her sight.

War between Persia and Egypt seems to have grown out of this oculistic incident. At all events, Herodotus (Thalia, III, 1) holds the following language: "Against this Amasis, Cambyses, son of Cyrus, made war, leading with him both others, his own subjects, and of the Grecians, Ionians and Aeonians. The cause of the war was this: Cambyses, having sent a herald into Egypt, demanded the daughter of Amasis; and he made this demand at the suggestion of an Egyptian physician, who out of spite served Amasis in this manner, because, having selected him out of all the physicians in Egypt, and torn him from

* This procedure, then called "cutting the skin that covers the pupil of the eye," is said to have been invented by Nebenchari.

his wife and children, he had sent him as a present to the Persians, when Cyrus, having sent to Amasis, required of him the best oculist in Egypt. The Egyptian, therefore, having this spite against him, urged on Cambyses by his suggestions, bidding him demand the daughter of Amasis, in order that if he should comply he might be grieved, or, if he refused, he might incur the hatred of Cambyses. But Amasis, dreading the power of the Persians, and being alarmed, knew not whether to give or to deny; for he was well aware that Cambyses purposed to take her, not as his wife, but his mistress. Having considered these things, he did as follows. There was a daughter of Apries, the former king, very tall and beautiful, the only survivor of the family; her name was Nitetis. This damsel, Amasis, having adorned with cloth of gold, sent to Persia as his own daughter. After a time, when Cambyses saluted her, addressing her by her father's name, the damsel said to him, 'O king, you do not perceive that you have been imposed upon by Amasis, who, having dressed me in rich attire, sent me to you, presenting me as his own daughter; whereas, in truth, I am the daughter of Apries, whom he, though he was his own master, put to death after he had incited the Egyptians to revolt.' These words in this accusation induced Cambyses, the son of Cyrus, being greatly enraged, to invade Egypt."—(T. H. S.)

Nebenhöhle. (G.) An accessory cavity.

Nebennieren. (G.) Suprarenal capsules.

Nebula. Opacity (of the cornea). See p. 3416, Vol. V, of this *Encyclopedia*.

Nebulizers. See **Sprays.**

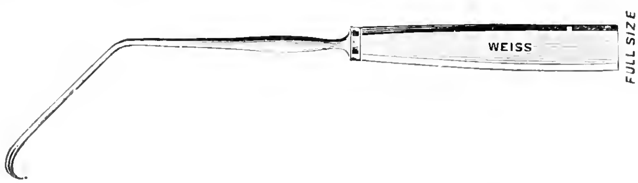
Necrobiosis. The progressive atrophy and decay of an organ.

Necrosis corneæ. See **Cornea, Infantile ulceration of the,** p. 3378, Vol. V of this *Encyclopedia*.

Needles for ophthalmic use. Needles in general. In the system of processes, about twenty-two in number, by which needles are now made, the first is the cutting of the coils of wire into two-needle lengths by a guillotine shearing-machine. The lengths of wire are next raised to a dull red heat and placed in loose bundles inside iron rings to be straightened by rolling backwards and forwards on a face plate. The wires are now pointed at both ends, by being passed, while revolving on their axes, across the face of a grindstone. The two-length wire blanks are automatically fed into a machine, which forms the prints or flats for the eyes, and thereafter the eyes are made by a punching machine. The double blanks are now "spitted" through their eyes on two wires. The burr made by the punch is removed by filing, the

wires are broken in two between the heads, and a row of single needles is left on each spit.

To temper the needles they are first hardened by being raised to a red heat in a furnace, after which they are dipped in cold cod-oil, and made less brittle by being led slowly over gas flames. The next step is to roll the needles on a smooth stone, and thus weed out those that are bent. In parcels of 50,000 they are next washed and scoured with soap, and the eyes are afterwards "blued" to soften them. The



Bowman's Double-curved Suture Needle.

eyes of the best needles are hand-polished with fine emery on flax threads. The next step is to grind the heads and set the points by hand on a rapidly revolving stone.

Critchett's Iridesis Needle.

An ingenious machine is employed for the final polishing of the shanks. After receiving a high polish the needles are not touched again by hand before leaving the factory, in order to prevent rust.

De Vicentiis' Needle.

The needles now require to be laid with their heads in one direction, and then to be separated into bundles according to length. Lastly, the needles are papered either by being spitted on cloth pasted to paper, or by being made up into small packets.—*(Standard Encyclopedia.)*

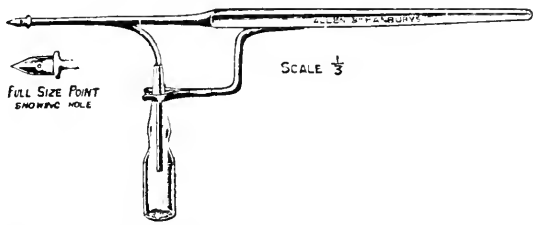
Needles for ordinary ophthalmic purposes—in lid operations, for example—closely resemble those employed in general surgery, but they are mostly smaller and should be more delicately made and more carefully ground and sharpened.

The accompanying illustrations are of needles intended mostly for special purposes; and many are mounted.

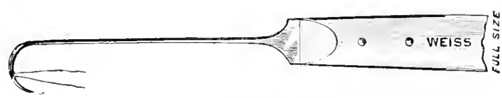
Needle, Cataract. A fine steel needle, usually with a lance-head and two cutting edges; used in various operations on the crystalline lens, such as opening the capsule, discission, keratonyxis, depression, and

reclination, also in tearing holes through secondary cataracts or through filmy membranes which block the pupil.

Needle, Couching. A needle having a thin, lozenge-shaped point, used in couching.



Dorrell's Needle for Taking Fluid from the Aqueous or Vitreous for Preparation of Vaccines.



Hulke's Curved Suture Needle.

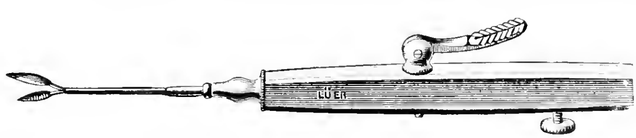
Maddox (*Ophthalmoscope*, X, p. 124, 1912) suggests that needles with very fine eyes may be used for a greater thickness of suture by

Lang's Broad Needle for Evacuation.

uniting the two halves of a double suture with flexible collodion. For twisting sutures he threads the needle, secures the needle in position

Lang's Paracentesis Needle.

at the loop by means of delicate thread, clamps each free end in a needle holder or hemostatic forceps, and spins one instrument while



Luer's Forceps-Needle.

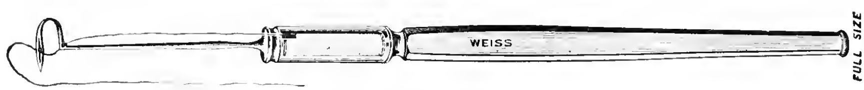
the other supports the suture. The two ends are then clamped together and the spinning repeated with the doubled suture, after which the two-ply suture is given any desired coating. Double-needled double

sutures may be prepared by doubling the suture on one needle, and then fraying the ends, uniting them with collodion, and passing the combined end through the second needle.

In performing the operation of discission, the models of knife-needles devised by Knapp, Hays, and Ziegler are excellent. See p. 118, Vol. I of this *Encyclopedia.*

Mooij's Eye Needle.

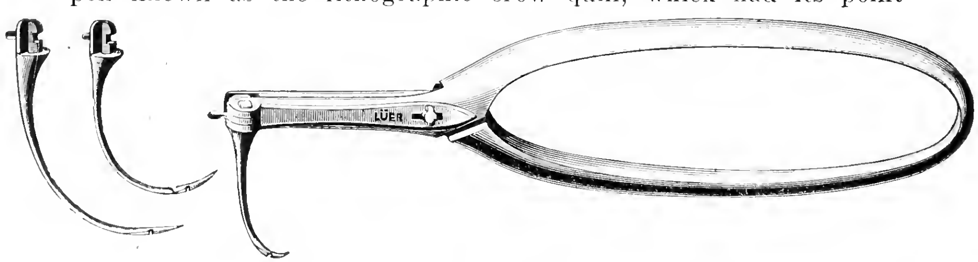
While de Wecker perfected the operation of tattooage of the cornea, Bader, Agnew, Tyson and Schoeler also contributed instruments for the same operation. Among other needles mounted on handles we have



Prince's Suture Needle, with Reel to Carry Silk.

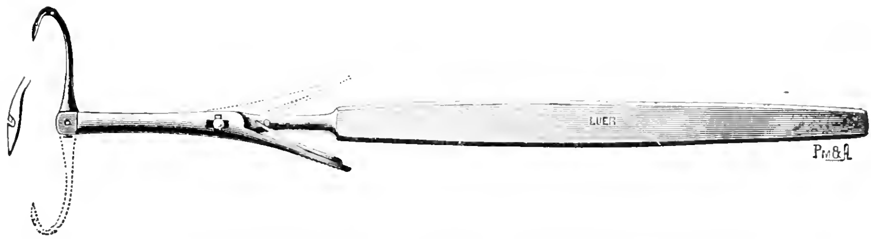
Bowman's stop-needle, Desmarres' paracentesis needle, Walton's grooved needle for soft cataract, Beer's cataract needle, and others.

Wm. Thomson's tattooing instrument consisted of a small steel pen known as the lithographic crow quill, which had its point

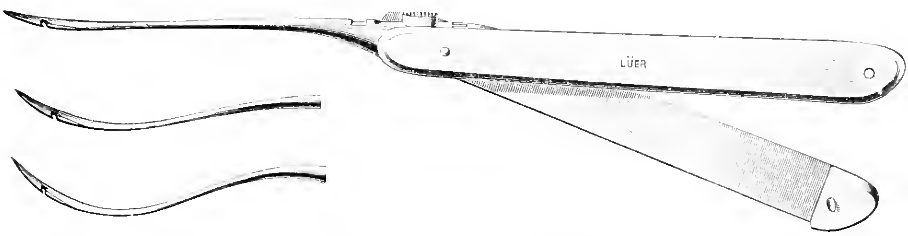


Reverdin's Mounted Suture Needles.

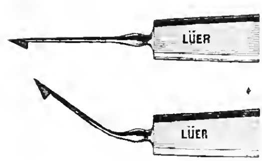
converted into a cutting surface. Its barrel held sufficient ink to complete the operation, and the pen was held with its trough uppermost. It was made to penetrate the laminæ of the cornea obliquely and by a slight lifting movement on withdrawal, a portion of ink was carried into each incision. See **Tattooing**; also **Sutures.**



Reverdin's Mounted Suture Needle.
Model for either right or left.



Reverdin's Pocket Suture Needle.

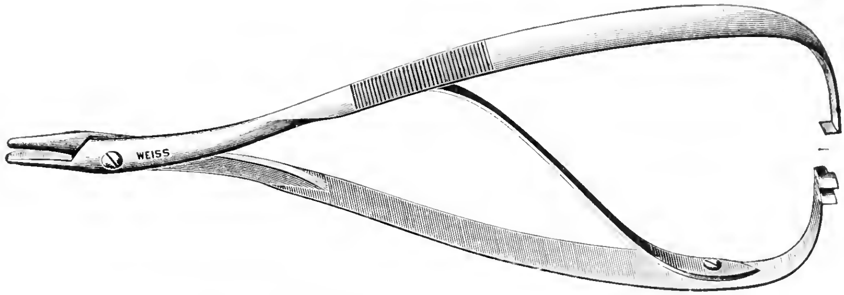


Stilling's Needles for Secondary Cataract.

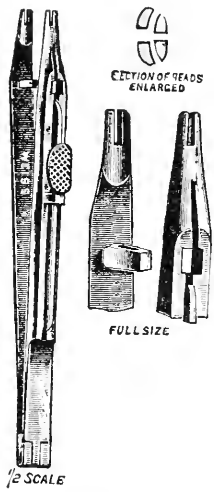
Walton's Grooved Needle for Soft Cataract.

Needle holders. The importance to the ophthalmic surgeon of a properly balanced, easily manipulated needle-holder is readily apparent. Some operators prefer the locked instrument because of greater ease of manipulation, others maintain that an instrument without lock is the safest, in that it does away with all shock and unsteadiness in freeing the needle. Little descriptive matter is here given, as the illustrations furnish the required information. The titles by which the instruments are commonly known are given alphabetically.

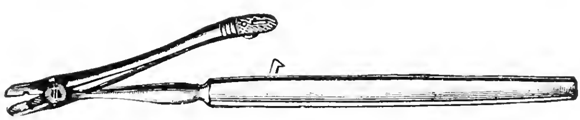
NEEDLE HOLDERS



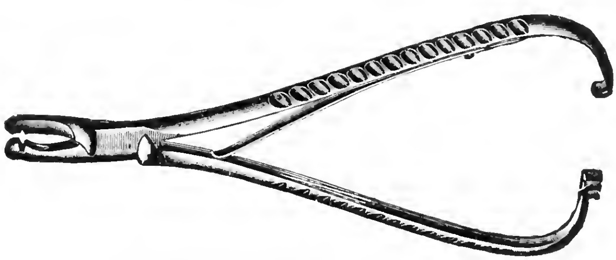
Allin's Needle Holder with Self-releasing Clutch.



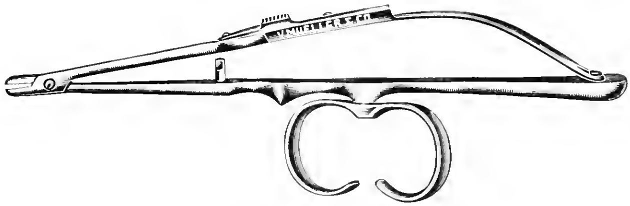
The Bardsley Needle Holder.



de Wecker's Needle Holder.

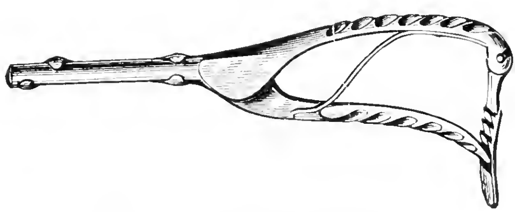


Ermold's Universal Needle Holder.

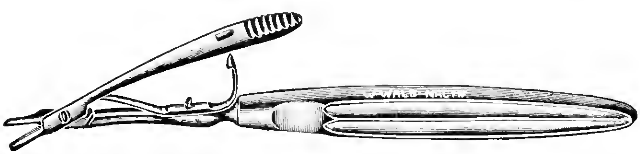


Fisher's Eye Needle Holder.

Galezowski's Needle Holder.

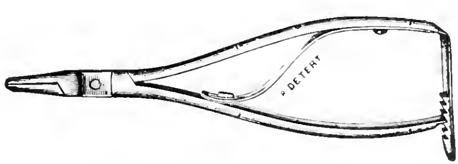


Hagedorn's Needle Holder.



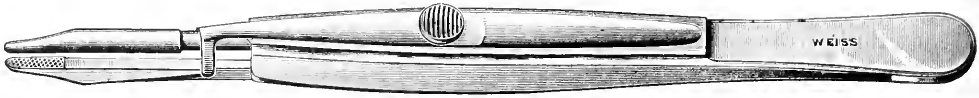
v. Heuss' Needle Holder.

Knapp's Needle Holder.

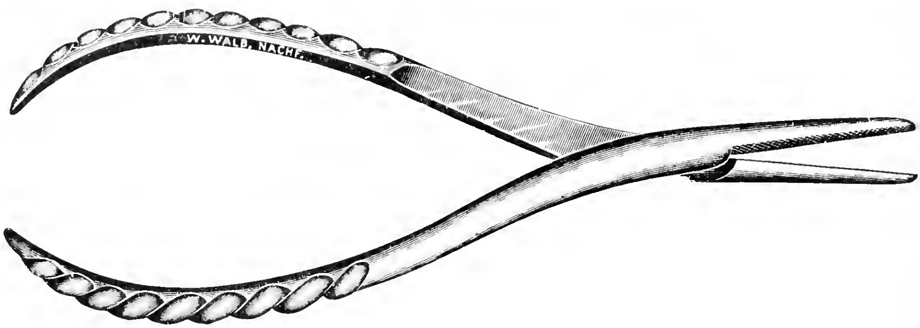


König's Needle Holder.

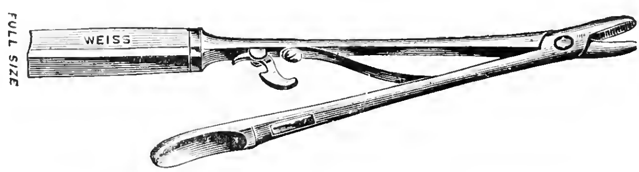
NEEDLE HOLDERS



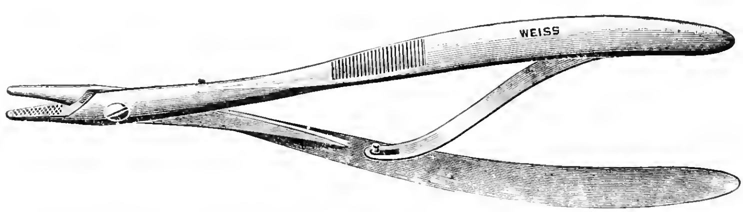
Landolt's Needle Holder with Sliding Catch.



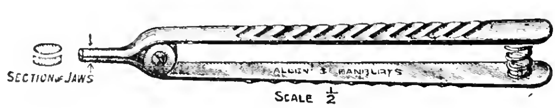
Langenbeck's Needle Holder.



Lever Action Needle Holder. (Weiss.)

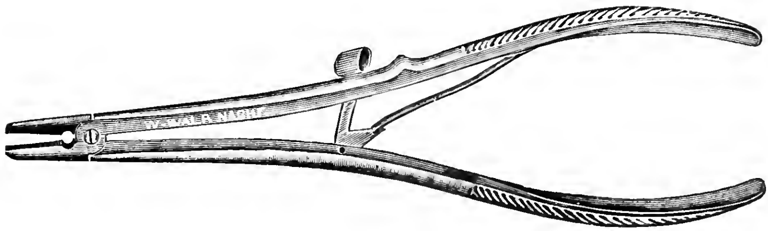


McIntosh's Needle Holder.

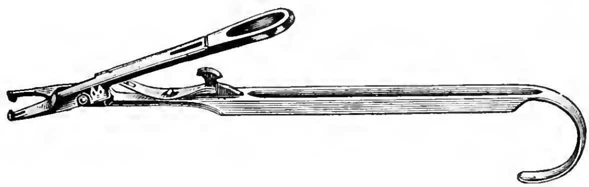


Norman's Needle Holder.

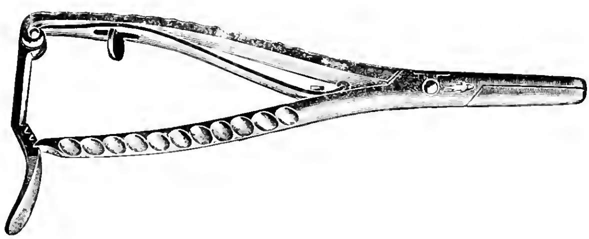
In Norman's needle-holder the grip of the jaws on the needle is maintained by a spiral spring between the handles, it being thus impossible for the needle to stick at a critical moment.



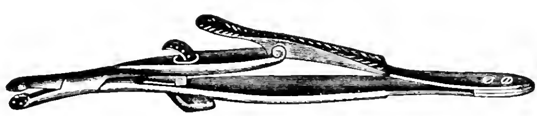
Reiner's Needle Holder.



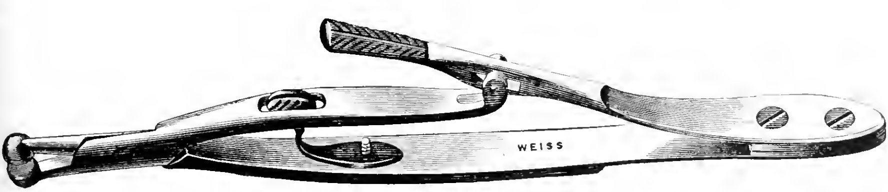
Richter's Needle Holder.



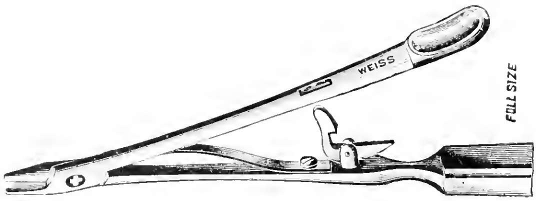
Roser's Needle Holder.



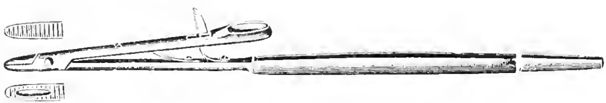
Sand's Needle Holder.



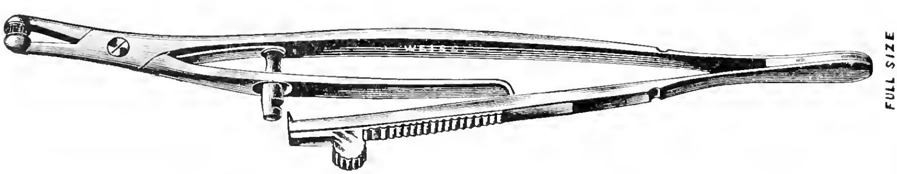
Saunders' Needle Holder.



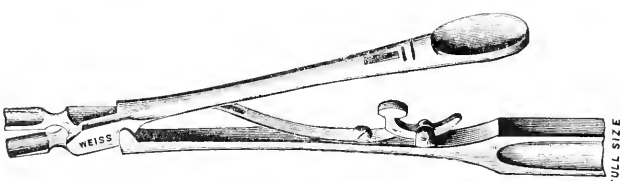
Silcock's Needle Holder.



Stevens' Needle Holder.



Weiss' Needle Holder with Improved Catch.



Worth's Needle Holder with Curved Blades.

Needle, Jacob's cataract. A No. 7 cambric needle with the point slightly curved; used to lacerate the capsule of a cataract.

Needling. Discission or puncture, chiefly of a cataract, with a needle. See p. 113, Vol. I, and p. 4022, Vol. VI of this *Encyclopedia*.

Neftel, William Basil. A well-known Russian-American neurologist, of some importance in ophthalmology. Born at Riga, Russia, Sept. 22, 1830, he received both his classical and his medical education at the University of St. Petersburg, taking the medical degree in 1852 with honors. He served throughout the Crimean War, and in 1857 was sent by the Russian government on an expedition into Central Asia. As a reward for his very distinguished services, he was made Hofrath (Aulic Councillor). For a number of years he studied in various European institutions at the Russian government's expense; among these a year and a half was spent at Würzburg.

In 1865 he emigrated to America, returning, however, in the following year to Europe. After two years further study, he came once more to America (in 1868), settling permanently in New York City. Although widely known as a neurologist, he devoted considerable attention to the eye, and wrote a number of articles on ophthalmic subjects. The most important of these is entitled "The Galvanic Reaction of the Optic and Auditory Nervous Apparatus in Healthy and Diseased Conditions."

The date of his death is not now ascertainable.—(T. H. S.)

Negative. In photography, a plate or film in which the natural lights and shades are reversed.

Negative accommodation. It is supposed by some that when the emmetropic eye is in a state of rest it is not quite adjusted for its farthest point of distinct vision, but can become so by a slight alteration in its accommodation, which is called negative, produced, according to Henke, by the action of the radial fibers of the ciliary muscle.

Negative after-images. In physiologic optics, what is bright in the image corresponds to what is dark in the object, and *vice versa.*

Negative bath. A dipping bath used for sensitization in the wet collodion process.

Negative convergence. See p. 3294, Vol. V of this *Encyclopedia.*

Negative crystals. Uniaxial crystals in which the index of refraction of the ordinary ray is greater than that of the extraordinary ray.

Negative distortion. See p. 4050, Vol. VI of this *Encyclopedia.*

Negative eyepiece. A combination of lenses which intercepts the rays from the objective before they come to a focus.

Negative focus. See p. 5237, Vol. VII of this *Encyclopedia.*

Negative image. The complementary image or visual sensation which results from stimulation by white light following color-selective retinal fatigue. See, also, p. 6169, Vol. VIII of this *Encyclopedia.*

Negative lens. Any lens thinner in the middle than on the edges.

Negative ocular. An ocular in which the real image is formed between the two lens systems of the ocular.

Negative picture. The image of an object developed and fixed on a film.

Negre blanc. (F.) Also called *blafard* and *kakerlaque.* According to Foster, this is a term originally applied by the Portuguese to white negroes met with on the west coast of Africa. See **Albinism,** p. 204, Vol. I, as well as p. 2951, Vol. IV of this *Encyclopedia.*

Negroid choroid. Abnormally dark choroid coat, such as is seen in pure negroes. Shoemaker's case, in one eye, occurred in an American

child, the other eye being the normal eye of a person of light complexion.

Negro's sign. This phenomenon is present in most cases of peripheral facial paralysis. Negro called it the *bulbo-palpebral hyperkinetic phenomenon;* it consists in the exaggerated position assumed by the eyeball when the patient is told to look up as high as he can. The eyeball on the side of the paralysis swings farther up than on the sound side, and in case both eyes are affected the phenomenon occurs on the side in which the paralysis is most severe.

Neigung. (G.) Inclination.

Neill, Hugh. An English surgeon, of considerable importance in ophthalmology. He practised in London till 1830, when he removed to Liverpool. In 1834 he was appointed surgeon to the Ophthalmic Infirmary, and to the Deaf and Dumb Institute. His life dates are not now ascertainable. Neill's ophthalmologic writings are as follows:

1. Reports of the Liverpool Eye and Ear Infirmary. (1834 et ann. seq.) 2. On the Cure of Cataract, with a Practical Summary of the Best Modes of Operating. Continental and British. (London, 1848.) 3. On Calabar Bean. (*Brit. Med. Jour.*, 1863.)—(T. H. S.)

Neisserbacterin. A preparation of killed bacteria suspended in normal salt solution which is injected for the purpose of raising the opsonic index of patients suffering from infection by that organism. Called also bacterin.

Neisseria gonorrhœa. Neisser's gonococcus.

Neisseria Micheli. The *trachomcoccus* of Michel; a micro-organism occurring in conjunctivitis ægyptiaca in the form of hyaline cocci resembling those of *Neisseria gonorrhϾ,* from 0.6 to 0.8 μ in their long and from 0.4 to 0.6 μ in their transverse diameter. In gelatin cultivations they become larger, forming yellowish colonies. See **Bacteriology of the eye.**

Neisserosis. A name for gonorrhea.

Neisser's stain. A method of staining bacilli of diphtheria by treating with 0.1 per cent. solution of methylene-blue, then with a 0.2 per cent. solution of Bismarck-brown. The bacilli are colored brown with a blue spot at each end. See **Bacteriology of the eye.**

Nélaton, Auguste. A famous Parisian surgeon, of some importance in ophthalmology. Born at Paris, June 17, 1807, he received his medical degree at the University of that city in 1836. In 1839 he was appointed associate, and, in 1851, full, professor of surgery in his alma mater. In 1863 he was made a Fellow of the Academy of Medicine, in 1867 a Fellow of the Institute, and in 1868 an Imperial Senator. He was a great teacher and operator, but neither a prolific nor

a very clear writer. His most important book was "*Eléments de Pathologie Chirurgicale*" (5 vols., Paris, 1844-60). In this work he devotes 335 pages to ophthalmology. Of more importance in our special field is his "Parallèle des Divers Modes Opératoires dans le Traitement de la Cataracte," a thesis of 136 pages presented in 1850 in competition for the chair of Operations and of Bandages. He invented a number of instruments, among them the well known "Nélaton's catheter." In 1867, at the age of 60, he resigned his teaching appointment, and six years later (Sept. 21, 1873) he died.—(T. H. S.)

Nelavan. The African lethargy, or sleeping disease.

Nelson, Joseph. An Irish ophthalmologist. Born in 1840 at Downpatrick, Ireland ,the son of a Unitarian minister, he graduated in medicine at Queen's University, and then began to study ophthalmology at Vienna under von Arlt. Soon, however, he went to India, where he engaged in business. For a time he served with Garibaldi against King Bomba, and was afterwards decorated and presented with a sword. Returning to Ireland in 1878, he began to practise ophthalmology at Belfast, and four years later was appointed ophthalmologist to the old Belfast Royal Hospital and to the Belfast Hospital for Sick Children. He was a charter member of the Ophthalmologic Society of the United Kingdom, and, at the time of his death, one of its vice-presidents. He wrote but little. He was a man of attractive personality, warm-hearted, genial, vivacious, and very generous and self-sacrificing. He died at Belfast Aug. 31, 1910, aged 69, leaving a widow and five children.—(T. H. S.)

Nematoda. A group of endoparasitic worms that include *trichina, ankylostoma, filaria, ascaris* and similar orders of ophthalmic interest, an account of which will be found under their proper headings in this *Encyclopedia*.

Nemonoscope. An instrument for viewing photographs.

Neo- A prefix signifying new.

Neoform. Basic tri-iodophenol bismuth: used as a dusting-powder in ulcers, etc.

Neogenesis. A form of regeneration or reproduction of tissue.

Neohymen. A false membrane.

Neon lights. Illuminants usually displayed in large (Geissler) tubes filled with neon gas (a rare product derived from the atmosphere) through which a current of electricity flows. The result is a reddish light said to be physiologically excellent and to increase the visual acuity 25 per cent.

Neoplasm. A new-growth or true tumor.

Neoplasms, Cerebral, Eye symptoms of. See **Brain tumor, Eye symptoms of.**

Neoplasty. Plastic restoration of lost parts.

Neorama. A panorama representing the interior of a large building within which, apparently, the spectator is placed.

Neosalvarsan. Ormsby (*J. A. M. A.*, Mar. 31, 1917), after an experience of more than six years with salvarsan and neosalvarsan, draws pretty definite general conclusions as to their value and also as to their limitations.

He says that salvarsan and neosalvarsan are the most efficient drugs yet discovered in the treatment of syphilis. Alone they have completely eradicated the infection in early cases before the Wassermann reaction has become positive. The large number of reinfections testify to this fact. Yet even in these cases mercury is recommended as an adjunct.

In all other cases, mercury should always be an accompaniment of salvarsan, and in many cases potassium iodid is indicated, especially in the so-called tertiary and latent cases and in those involving the nervous system. The ability of potassium iodid to remove infiltrations, gummas and nodules, together with its marked effect on vascular implications, renders its use imperative.

The major number of reactions following the use of salvarsan and neosalvarsan are insignificant. The more serious ones are to be avoided, so far as possible, by an initial small dose to test the tolerance of the patient, by careful attention to details in administrative technic, by recognizing contraindications, and, in the case of early, active syphilis, preceding the salvarsan treatment with mercury, to prevent neuro-recurrences; and finally, by giving sufficient treatment to control the disease. Emphasis must be laid on the latter statement, as much harm may be done by its apparent effect, the degree of relief placing the patient in a position of false security; therefore, sufficient treatment is demanded to prevent recurrences and relapses.

Many of the earlier cases, following insufficient treatment, of rapid onset of symptoms which ordinarily come late in the disease, such as nervous involvement and precocious tertiary manifestations, were eradicated by more salvarsan, and now should be entirely avoided by treatment of sufficient intensity and amount to control the disorder.

The treatment of syphilis with salvarsan and neosalvarsan has caused an intensive study over the entire world of the question of efficient management of the disease, to such a degree that great lessons have been learned and much good accomplished. Their ultimate value will require many more years to determine.

As to a choice between the two drugs, salvarsan and neosalvarsan, the extensive use of both proclaims their efficiency, so that individual circumstances with the physician and patient must decide which, under the circumstances, is to be selected. The apparent preponderance of opinion that salvarsan is more efficient is offset to a degree by the difficulties of its administration and the more frequent reactions following its use.

The problem of reducing toxicity to a minimum rests with the producers of the drug.

Concerning the dangers following the individual injections, many warnings have been given to exercise care after the fourth injection. The warning has not been accompanied by tabulated results showing proof of this contention. On the other hand, the statistics now available show that the major portion of severe reactions, untoward results and fatalities have followed the first injection, and that with subsequent injections these results were greatly decreased.

The efficiency of salvarsan and neosalvarsan is of such a high order, and the limitations are so comparatively few that they will probably hold an important place in the future treatment of syphilis. The clinical results are striking, and in addition their effect serologically is such that the question of their abandonment can be conceived only by the discovery of a more potent remedial agent.

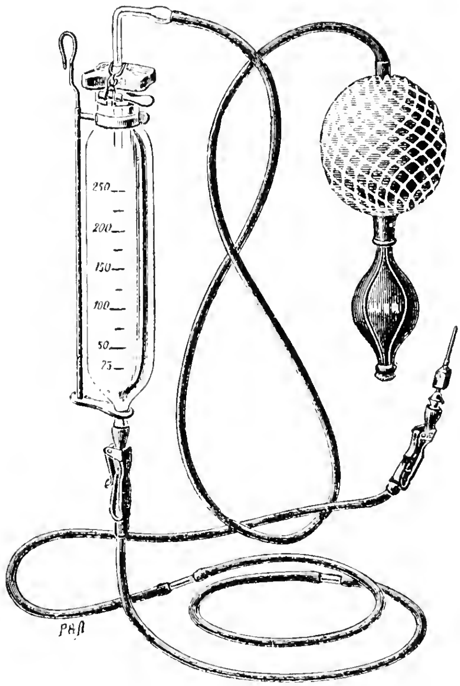
This substitute for salvarsan, neosalvarsan, or arsenobenzol ("606"), is a product of salvarsan and formaldehyd sulphoxyl-acid sodium. It is of neutral reaction, less toxic and more soluble than salvarsan. It is also called "914." It has been used locally in luetic eye diseases as well as given internally, hypodermically and intravenously in the general treatment of ocular infections.

When employed by intravenous injection a special syringe is generally employed. The accompanying figure shows one of these, so arranged that the dosage can be accurately measured and given free of air or other contamination.

Rosenmeyer (*Woch. f. Ther. u. Hyg. des Auges*, Dec. 12, 1912), administered neosalvarsan locally in a case of interstitial keratitis due to congenital lues. Treatment with mercurials had proved ineffectual. In one eye he introduced several grains of the powder, in the other instilled a few drops of a 2 per cent. solution. Within two days he noted clearing of the opacities, and in the eye treated with the solution, subsidence of inflammatory infiltration was noted. Continued use of atropin and neosalvarsan in one solution also resulted in marked improvement.

Hoehl (*Woch. f. Ther. u. Hyg. des Auges*, March 20, 1913) treated

seven cases of parenchymatous keratitis (three acute, four regressive) with freshly prepared 2½ per cent. neosalvarsan solution, instilling one or two drops twice a day for four weeks. In no case was any particular improvement noted. This is not surprising in the light of recent investigations, which suggest, in some instances, a nonspirochetic affection of the human cornea.



Apparatus for the Intravenous Injection of Neosalvarsan. (Luer.)

E. Schreiber (*Münch. Med. Wochenschr.*, 36, 1913) remarks that during early experiences with salvarsan a concentrated solution was employed, so as to shorten the time of injection and simplify the technique, but it was found that the stronger the solution the greater the toxicity. It is quite otherwise in the case of neosalvarsan. Toxicological experiments proved that concentrated solutions are no more dangerous than weaker ones. How is this difference between the two preparations to be explained? Ehrlich has always emphasized the fact that the toxicity of salvarsan depended upon the oxidation products, but neosalvarsan has more tendency to auto-oxidation than old salvarsan. Now if we dissolve some neosalvarsan with 10 ccm. in a closed vessel the auto-oxidation will naturally be less than if a greater amount

of water were used, in which case the contact of the preparation with the oxygen of the air and the water, when the mixture is shaken about, is much more complete. Moreover, when we use neosalvarsan in concentrated solution we produce a solution which is nearly isotonic with the blood, which, in the case of salvarsan, can only be obtained by much weaker solutions. We now dissolve .75 g. in 10 ccm. of physiological salt solution and make the injection with an ordinary 10 ccm. syringe. Schreiber warns against using anything but sodium chloride solution, for distilled water, by means of its hemolytic action, may give unfavorable results. It is also thought that with repeated injections the unpleasant symptoms produced are the result of a form of anaphylaxis. It is again possible that the oxygen of the blood combines with the neosalvarsan to form toxic products. Since making a practice of giving the injections every eight days with .75 g. as the highest dose Schreiber has seen no exanthema and the gastric and intestinal symptoms have been very mild. Great care must be exercised, on account of the concentration of the solution, to allow none to be injected under the skin. The needle is inserted into the vein, and as soon as the blood flows from the needle, the syringe is attached and the fluid injected.

Maucione (*Congrès International d'Ophtalmologie,* 1914) also believes that neosalvarsan is preferable to salvarsan on account of its simpler technique and the absence of signs of intolerance. He agrees with those observers who state that neuro-recurrences are not due to the drug, but to new manifestations of the disease. The results of neosalvarsan treatment have been best in acute and subacute inflammatory affections, less marked in the chronic and hereditary forms, and negative in the degenerative forms. If the disease appears to be cured, but the Wassermann reaction is still positive, the writer advises continuance of the neosalvarsan in smaller doses, combined with the administration of mercury and potassium iodide.

More recent experiences seem to dampen the ardor of the earlier advocates of this drug. Darier (*Clinique Ophtal.,* June, 1913), after its subconjunctival employment, and Fromaget (*Ophtal. Provinciale,* June, 1914), giving it by intravenous injection, are rather lukewarm in their praises of it. The latter writer for eight months treated all cases of syphilitic keratitis with neosalvarsan, injected intravenously. The object was to discover whether this had any advantages over mercurial treatment. He briefly records the history and method of treatment of seven cases, and comes to the following conclusions: Neosalvarsan does not cure congenital syphilitic keratitis; the condition is not even checked or arrested; and it certainly does not prevent the

other eye from being attacked. The duration is not shortened. The drug has no favorable action on the symptoms which accompany the keratitis. It however improves the general condition of the patient and in this respect it differs from the mercurial preparations. In acquired syphilis the results are satisfactory. The author believes that in congenital cases the organisms must be in some unknown state whereby they resist the action of chemical substances; the means must therefore be discovered to render them susceptible to toxic substances. See, also, **Salvarsan**; as well as **Syphilis of the eye**; **Arsenical poisoning**, and **Toxic amblyopia.**

Nephela. A white spot (scar) on the cornea.

Nephelometer. An instrument for measuring the cloudiness of the sky.

Nephelopia. Defect of vision from cloudiness of the cornea.

Nepheloscope. A piece of apparatus for illustrating the formation of cloud.

Nephoscope. An instrument used in the observation of clouds to determine their direction, angular elevation, and relative velocity. It is made in various forms, the usual being a horizontal mirror, with scales, sighting-rods, etc.

Nephria. A name for Bright's disease.

Nephritis, Eye symptoms of. See **Bright's disease, Ocular symptoms of,** p. 1296, Vol. II of this *Encyclopedia.* To the matter therein discussed may be added here a full abstract of the ophthalmic portion of an admirable paper by George Slocum (*Jour. Am. Med. Assocn.*, July 1, 1916) in which especially the ophthalmoscopic changes in various forms of the so-called Bright's disease are discussed, a large number of cases having been studied in five divisions as follows: A, chronic interstitial nephritis; B, chronic nephritis; C, acute nephritis; D, hypertension, and E, miscellaneous cases.

He found edema present in 93 per cent. of the cases. The fact that it was found in all cases of hypertension and in 96.7 per cent. of the cases of chronic interstitial nephritis seems to indicate a vascular rather than a nephritic origin. In the few cases of acute nephritis examined it was the least frequent, which tends to support such a conclusion. Its relation to the blood pressure does not appear, as it was present in the cases of chronic nephritis with lower blood pressure, quite as regularly as in other chronic cases of either parenchymatous or interstitial type: in the cases of acute nephritis when the blood pressure was low it was present in but 75 per cent., and in addition it was present in the one case showing rather high arterial tension. Congestion and slight swelling of the disk were present in 39.7 per cent. of the cases, being

rather more frequent in chronic than in acute nephritis, but most frequent in hypertension.

All of the cases of chronic interstitial nephritis with swollen disks of 1 D. or more occurred in cases of marked increase in blood pressure. Especially is this the case when the age of the patient is considered.

In the chronic nephritis cases showing swelling of the disk, the white blood cells were increased in the cases in which a blood count was made, though this feature was not so noticeable in the interstitial type.

In the parenchymatous form elimination was retarded and blood urea increased in three cases, a marked feature in one instance. Although in this case the swelling was not great, there were typical radiating macular changes.

Macular changes were present in all of the choked disk cases in parenchymatous nephritis and in three out of six cases of interstitial nephritis. Three out of four of the former were of the radiating type, and one of the latter. Swelling of the disk was more frequently associated with poor elimination, nephritic toxemia; on the other hand, macular changes were more degenerative in type, possibly in part dependent on the etiology of the kidney lesion, metabolic or blood toxic. In one case of hypertension in which there was some evidence of nephritis, arteriosclerotic type, the disk in one eye was swollen 1 D., elimination low limit of normal, blood pressure high.

Periarteritis was nearly twice as frequent in chronic nephritis as in interstitial, but why it should also be twice as frequent in hypertension as in interstitial is not easily explained.

Endarteritis was least frequent in acute nephritis, and equally infrequent in the other nephritic cases. It is not surprising that it should be more frequent in hypertension, as several of these cases showed evidence of general arteriosclerosis; that it should be so frequent in the miscellaneous cases is probably due to the fact that of these the first three cases showed high blood pressure.

Tortuous or contracted arteries seem to have been mostly associated with high blood pressure, though they were relatively more frequent in the acute than in the chronic group. They are probably associated with the other vascular changes.

Silver wire arteries seem to be a feature of a late stage of interstitial nephritis, 30 per cent.; they were present in 15 per cent. of cases of hypertension. They may be dependent on the cause of angiosclerosis rather than directly on increased blood pressure.

Corkscrew vessels in the macula were present in 10 per cent. of the interstitial and 16.6 per cent. of the chronic nephritis cases. They are

probably due to long continued interference with the terminal circulation in the retinal vessels caused by the toxic substances present in the blood in nephritis rather than to increased blood pressure, for they were noted but once in the cases of hypertension and not at all in the other cases.

Arteriovenous compression was present to a marked degree, 70 per cent. Judging from its regular distribution throughout all five series, this feature would seem to be symptomatic of angiosclerosis rather than to be due to the poisons which cause the nephritis or the toxic substances resulting from the kidney lesions.

Venous tortuosities and irregularities were relatively most frequent in the acute cases, but they were present in 65.7 per cent. of all, and in 92 per cent. of hypertension cases. They are probably caused by both toxic retention and angiosclerotic changes. The same observation might be made with regard to periphlebitis, though it was relatively quite infrequent.

Hemorrhages were present in 53.4 per cent. of all cases. Interstitial nephritis showed hemorrhages in 73.3 per cent.; hypertension and chronic nephritis in 54 and 50 per cent., respectively. They were absent in the acute cases and present in one case of chronic bronchitis. In this case, although the blood pressure was only 135 mm. of mercury, and the urine was normal, there were distinct evidences of retinal angiosclerosis in the eye in which the hemorrhage occurred. This case was the only one in the series having a low blood pressure. In all the other cases of retinal hemorrhage, increased blood pressure was a prominent feature, excepting in some of the cases of chronic nephritis. Retarded or markedly deficient elimination was present in 70 per cent. of cases showing hemorrhages. They were more frequent in cases having a large amount of albumin than in those showing a small amount, in the ratio of 4:9.

Retinal detachment was present only in interstitial nephritis and hypertension. In one case the detachment was bilateral and rather extensive; in the other cases the detachment was small, and occurred in only one eye. All these cases showed a distinctly high blood pressure. In the two detachment cases in which the elimination test was made the result gave the low limit of normal.

Macular changes were mentioned in connection with the cases of severe optic neuritis; there remain, however, a few interesting features. The radiating type so commonly mentioned as characteristic of nephritis was present in only 6.8 per cent. of all cases. Of these, it was present in 22 per cent. of the chronic nephritis cases, and in only one, or 3.3 per cent. of the interstitial nephritis cases. In the latter case

the blood pressure was high, elimination retarded, blood urea increased. In two of the cases found in chronic nephritis there was high blood pressure; three showed marked swelling of the disk; in the fourth the disk was congested. Elimination was low and blood urea increased or high in the cases in which this test was made. Radiating macular changes may therefore be said to be nephritic toxic with high blood pressure and angiosclerotic changes uniformly present.

Other macular changes were found to be the most prevalent in interstitial nephritis, 43.3 per cent., and in hypertension, 46 per cent. They were a feature of 11 per cent. of chronic nephritis. In the interstitial type, high blood pressure was present in every case of a typical macular change. The majority of these cases in which these tests were made showed low elimination and high blood urea. From these cases it would seem that as regards etiology, both radiating macular changes and atypical macular changes are nephritic toxic and angiosclerotic, associated with high blood pressure, but that the former are more common in chronic nephritis, while the latter are more common in interstitial nephritis and hypertension.

The choroidal changes noted are not easy to account for, but as they were more prevalent in interstitial nephritis and hypertension, they are probably angiosclerotic in origin, though a definite sclerosis of the choroidal vessels was made out in but one case, one of interstitial nephritis. They were noted in three cases, where they seem to have been associated with no particular type of lesion.

The thirty cases showing changes of an inflammatory type include the cases of optic neuritis, exudative retinitis, macular exudates, etc. They seem to have considerable relation to a retarded elimination, increased blood urea, and frequently to an increase in the white blood cells.

Atrophic changes apparently have less significance than inflammatory changes, and are more difficult to explain in these groups. In the main they were associated with high blood pressure and fairly good elimination.

In the cases of interstitial nephritis the serious retinal changes seen in high blood pressure are numerous and significant, and the fact that these are, to a large extent, dependent on angiosclerosis seems to be established by the occurrence of these lesions in much the same relative frequency in hypertension. The much smaller percentage, 55.5, of high blood pressure in the cases of chronic nephritis is worthy of notice, especially when we find nearly as large a percentage of serious retinal lesions in the seven cases having moderately increased blood pressure. In the one case of chronic nephritis having a nearly normal

blood pressure the lesions were practically the same as those seen in acute nephritis. These facts support the belief that many of the serious fundus lesions of nephritis are, in part at least, dependent on some other factor than angiosclerosis.

Pursuing this subject further, the striking fact appears that three out of four cases of so-called choked disk were seen in chronic nephritis with slow elimination, while but two out of six similar cases, marked swelling of the disk were seen in slow elimination in interstitial nephritis, and none in hypertension. A similar distribution of fundus lesions in chronic nephritis appears in cases showing slow elimination; less than one fourth of Series B had normal or fair elimination, and if one choked disk, one silver wire artery and two cases with hemorrhagic lesions may be excepted, good elimination seems to be protective of the fundus in chronic nephritis. In interstitial nephritis good elimination appears to offer less protection, for there were seven cases in each class, that is, in slow elimination and normal elimination, and there were nearly as many retinal lesions in the one as in the other, although the lesions were slightly more numerous in the cases in which elimination was slow; for example, there were two cases of choked disk and nearly twice as many hemorrhages in the latter condition, which goes to show that even in angiosclerotic cases, toxemia often plays a significant part.

From the standpoint of the amount of albumin found in the urine, there are in interstitial nephritis fifteen cases in which the amount was large, and an equal number with a small amount. All the cases of choked disk found in interstitial nephritis were present in cases in which the albumin was in large amount. The silver wire and corkscrew arteries were more numerous with a small amount of albumin, while hemorrhages were much more numerous where the amount was large. In chronic nephritis, on the other hand, there were twice as many cases with hemorrhages having a large amount of albumin. Two cases of choked disk were found in both large and small amounts of albumin. Of the other fundus lesions found in albuminuria, hemorrhages seem to have been about equally distributed, although they were relatively a little more frequent in small amounts of albumin than in large; this perhaps goes to show that when considered in relation to both angiosclerosis and slow elimination, toxemia and its results in the production of fundus lesions are not closely related to the amount of albumin found in the urine in any given case. Albuminuria does not appear to have had much if any significance in the cases of hypertension, and almost none at all in the acute cases seen.

Low red blood cell count, as indicating relative anemia, is of more

than passing interest. Three of the six cases of choked disk in interstitial nephritis, two of the four cases of choked disk in chronic nephritis, 50 per cent. of each, showed this feature; silver wire arteries and hemorrhages were also, though in less striking degree, features of low red blood cell count. The one case of relative anemia in hypertension showed nothing striking.

Only five cases of interstitial nephritis, 16.7 per cent., showed an increased white blood cell count. The lesions seen in this series could all be attributed to angiosclerosis. On the other hand, there were five cases of chronic nephritis, 27.7 per cent., having a high white blood cell count. Choked disk appears here in two cases, 50 per cent. of the cases found in chronic nephritis. Silver wire or corkscrew arteries were also relatively numerous, though there was but one case showing hemorrhages. Three out of the five cases of acute nephritis had a relatively high white blood cell count: there were no cases of relatively low red blood cell count in this series. There seemed to be no relation between either the red or white blood cell count and the ophthalmoscopic features of acute nephritis.

The relation between the histopathology of the renal lesions of nephritis and that of the fundus lesions found with the ophthalmoscope in nephritis and hypertension is quite as interesting as the relation between these findings and the features of nephritis already discussed. In each case we have an organ made up largely of highly differentiated epithelial cells, differing widely as to embryologic origin, but each bound together by a supporting framework, and each having a rich and peculiar type of vascular organization and blood supply. As in diseases of the kidney, so in diseases of the retina, the changes which take place are of a degenerative type, often dependent on the associated or preceding vascular changes.

Edema, which was common to all classes and almost constantly present, occurs in the earliest stages of retinitis as a diffuse edema affecting the disk, retina and macula. It gives rise to a watery haziness or opalescence, with increase in the retinal depth as measured by the ophthalmoscopic parallax. Later, localized edema may occur in the retinal substance forming cystic spaces, which may become filled with hyalin or fat derived from the degenerating arterioles with subsequent formation of cholesterin crystals. When the spaces become large and distended, they may rupture externally, giving rise to subretinal fluid with detachment. As a result of the pressure, edema and intracystic exudate, the nerve elements degenerate, the fluid filling the spaces changes to hyalin, and more or less well defined white spots or areas develop. In the severe types, endothelial leukocytes may pene-

trate the hyaloid boundary and lead to the formation of white bands, or in more severe cases to proliferating retinitis.

The vascular changes on which the retinal changes, to so large a degree, depend, are generally the result of hyalin necrosis with fat formation due to changes in the intima. Endarteritis is followed later by deposits of lime salts in the necrotic areas of the intima. The perivascular changes are due either to albuminous exudate followed by hyalin deposits in the perivascular sheaths, or to a peculiar type of hyalin degeneration seen in other parts of the central nervous system, in which there is deposited around the wall of the artery minute droplets of hyalin which fuse to form a complete sheath for the vessel; the cause of this formation is not known; calcification often occurs. Hemorrhages when small may undergo complete absorption through the activity of the endothelial leukocytes. If large, the blood pigment may be partially absorbed through the same means, while fatty degeneration of the coagula followed by cholesterin formation and the development of cystoid spaces, with hyalin and other changes, may lead to permanent white patches more or less associated with unabsorbed irregularly arranged blood pigment.

Joseph Collins (*Journ. Amer. Med. Assocn.*, p. 1314, May 5, 1917) reports a case of chronic nephritis simulating the symptoms of cerebral neoplasm. He finds a few references to similar cases in the literature, and remarks that if papilledema is the result of increased pressure of fluid in the vaginal sheath of the optic nerve, the pressure may in this case be the manifestation of edema, such as occurs in other parts of the body constantly in chronic nephritis. If we assume that this is the true explanation of the pathogenesis of the condition, the papilledema should subside under the use of measures which facilitate the disappearance of edema in other parts of the body. If, on the other hand, the neuritis is the result of the activity of toxic matter acting on the termination of the optic nerve, it is not likely that it will subside, for unfortunately we are not in a position to do the work of the kidneys artificially or vigorously.

Nernst lamp. See **Lamps, Ophthalmic**; also p. 4606, Vol. VI, of this *Encyclopedia*.

Nervanin. A local anesthetic, said to be far better and safer than cocain: its chlorhydrate is scarcely poisonous unless given in enormous doses. Dose, 4-8 gr. (0.266-0.533 gm.).

Nerve, Diseases of the optic. See **Optic nerve, Diseases of the.**

Nerve, Facial. See p. 5136, Vol. VII of this *Encyclopedia*.

Nerve-fibres, Medullated. See **Nerve-fibres, Opaque.**

Nerve-fibres, Opaque. MEDULLATED NERVE-FIBRES. This condition is

due to the fact that the medullary sheath of the optic nerve axis-cylinders is continued into the retina and appears as bright, white, striated patches found usually above or below the optic papilla and presenting a frayed or flame-like extremity. Exceptionally they are not contiguous to the disc, in which event they may be mistaken for fatty deposits. Sometimes the retinal vessels are partly covered by the opaque fibres. The existence of opaque nerve-fibres does not often influence visual acuity.—(J. M. B.)

Numerous observations as to variations in the distribution and in the ophthalmoscopic appearances of opaque nerve fibers are recorded in literature. For example, Schnaudigel has demonstrated a case in which all the nerve fibers leaving the optic disk were furnished with medullary sheaths except those of the papillomacular bundle. The eye had always been myopic; vision equalled counting fingers at one-half meter. Ginsberg reports a case in which there were three patches of opaque nerve fibers distant 5 or 6 disk diameters from the optic disk. The largest, 3 d.d. long, lay about its length above the macula. The eye had full vision and no scotoma could be demonstrated. Höeg studied the visual field in cases of opaque nerve fibers, with test objects of different sizes. He found the enlargement of the blind spot was not so great as to correspond with the area of the patch of opaque nerve fibers. Evidently considerable light penetrated the nerve fibers to the percipient layer of the retina. Rönne has pointed out that this also was the case with white exudates in the retina, which, therefore, did not give rise to absolute scotoma.

Nerve, Fifth. See p. 5193, Vol. VII of this *Encyclopedia.*

Nerve, Fourth. See p. 5281, Vol. VII of this *Encyclopedia.*

Nerve, Lachrymal. See p. 410, Vol. I of this *Encyclopedia.*

Nervenfaserscheide. (G.) The sheath of Schwann.

Nervenfaserschicht. (G.) Nerve fibre layer.

Nervenhaut des Auges. (G.) Retina.

Nerve, Ophthalmic. See p. 409, Vol. I of this *Encyclopedia.*

Nerve, Optic, Atrophy of the. See p. 668, Vol. I of this *Encyclopedia;* as well as **Neurology of the eye.**

Nerve, Optic. The second cranial nerve of Willis and Sömmering, the special nerve of the sense of sight. It passes forward and outward, rounded in form and covered with a sheath, from the arachnoid to the optic foramen. As it passes through the foramen it receives a sheath from the dura, which sheath divides in the orbit into two layers, one continuous with the periosteum of the orbit, the other continued as a sheath for the nerve as far as the sclerotic. The nerve pierces the sclerotic and the choroid at the back of the eye, a little to the nasal

side of its centre, and expands into the retina. See p. 395, Vol. I; also p. 5965, Vol. VIII of this *Encyclopedia.*

Nerves, Ciliary. See **Anatomy of the eye**; as well p. 5955, Vol. VIII of this *Encyclopedia.*

Nerve, Sixth. See **Neurology of the eye,** as well as p. 411, Vol I of this *Encyclopedia.*

Nerve, Third. See p. 409, Vol. I of this *Encyclopedia,* as well as **Neurology of the eye.**

Nerve, Tiedemann's. A plexus of nerve-fibrils around the central artery of the retina, arising from the ciliary nerves.

Nerve, Trigeminal. See **Nerve, Fifth.**

Nervine. Affecting the nerves; allaying nervous excitement; a remedy for nervous disorders; a nerve-tonic; a therapeutic preparation of the gray substance of the brains of sheep; a proprietary remedy for gout, rheumatism, and neuralgia.

Nervous diseases, Ocular manifestations of. See **Neurology of the eye.**

Nervous system, Ocular relaticns of the. See **Neurology of the eye,** as well as such headings as **Optic nerve; Hypophysis; Intracranial visual apparatus; Choked disk; Tabes; Brain tumor.**

Nervus abducens. Sixth nerve.

Nervus facialis. See p. 5137, Vol. VII of this *Encyclopedia.*

Nervus frontalis. See p. 5305, Vol. VII of this *Encyclopedia.*

Nervus infraorbitalis. See p. 6197, Vol. VIII of this *Encyclopedia.*

Nervus infratrochlearis. See p. 6198, Vol. VIII of this *Encyclopedia.*

Nervus lacrimalis. This is a nerve of sensation, a branch of the ophthalmic division of the trifacial, supplied to the conjunctiva, lacrimal gland and upper lid.

Nervus nasociliaris. This is one of the branches of the ophthalmic nerve.

Nervus oculomotorius. Third nerve.

Nervus ophthalmicus. The chief nerve of (ocular) sensation. It is the first division of the fifth nerve, arising from the upper part of the Gasserian ganglion. This nerve takes the shape of a short, flattened band, about an inch long, which passes forward along the outer wall of the cavernous sinus and, just before entering the orbit through the sphenoidal fissure, divides into the frontal, lacrymal, and nasociliary nerves. See **Anatomy of the eye.**

Nervus opticus. See **Nerve, Optic.**

Nervus supraorbitalis. (L.) This branch of the trigeminus enters the orbit through the superior orbital fissure and with the supraorbital artery passes out through the supraorbital canal to be supplied to the skin of the forehead.

Nervus supratrochlearis. This nerve is the terminal branch of the supraorbital. It passes along the orbital wall lying upon the superior oblique, joining to and forming a network with the infratrochlear nerve.

Nervus trigeminus. Fifth nerve.

Nervus trochlearis. Fourth nerve. See p. 5280, Vol. VII, of this *Encyclopedia.*

Nesselfäden. (G.) Muslin threads.

Nests, Cancer. Masses of concentrically arranged cells seen in cancerous growths.

Net, Chromidial. A network of chromatin staining material in the protoplasm of certain cells. It has the properties of active nuclear material.

Netteté. (F.) Sharpness.

Nettle. *Urtica dioica.* According to Archigenes, the nettle was used as a poultice in his day for any affection of the eye accompanied by profuse discharge.—(T. H. S.)

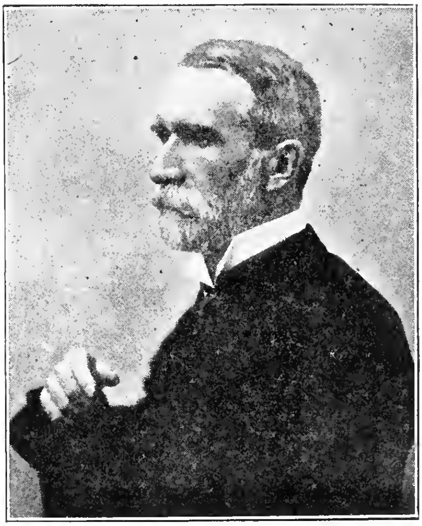
Nettle-rash. Hives. A skin disease characterized by the sudden appearance of smooth, slightly elevated patches, which are usually whiter than the surrounding skin and attended by severe itching. The eruption, which may involve the palpebral skin, rarely lasts longer than two days. It may, however, exist in a chronic form. The disorder often arises from irritation of the gastro-intestinal, pulmonary, or urinary mucous membrane. The ingestion of certain foods, such as shell-fish, is apt to produce it. Menstruation or mental emotion may also be a cause.

Nettleship, Edward. A famous English ophthalmologist, author of the world-renowned little volume, "*Diseases of the Eye.*" Born at Kettering, Northamptonshire, England, Mar. 3, 1845, the fourth son of Henry John Nettleship, a solicitor of that place, he was one of a remarkable quartet of brothers. The eldest son, Henry, was Corpus Professor of Latin at Oxford; the second, John Trivett, was a famous painter of animals; and the youngest, Richard Lewis, a man of great promise who died very young, was Fellow and Tutor of Balliol College, Oxford. The subject of this sketch received his early education at the Kettering Grammar School and Royal Agricultural College at Cirencester. He then proceeded to study medicine both human and veterinary at King's College, London, at the London Hospital, and at the Royal Veterinary College. In 1867 he received the degree of M. R. C. V. S., and in 1868 that of M. R. C. S. (Eng.). In 1870 he was made F. R. C. S. (Eng.).

In 1867 or 1868, he began to study ophthalmology. For a time he was assistant to Jonathan Hutchinson at Moorfields, and in 1871 he

was appointed Curator and Librarian to the same hospital. He was for many years ophthalmic surgeon at St. Thomas's Hospital and at Moorfields, and, for shorter periods, at the South London Ophthalmic Hospital (now the Royal Eye Hospital) and at the Hospital for Sick Children, Great Ormond St. In 1895, resigning his position on the active staff at St. Thomas's, he was appointed Consulting Ophthalmic Surgeon to that institution. In 1898 he resigned his position at Moorfields, where he had labored so assiduously for many years.

Nettleship was one of the founders (1880) of the Ophthalmological Society of the United Kingdom. He was also the first Surgical Secretary of the Society. From 1895 till '97 he was President of this body, and in 1909 he delivered before it the "Bowman Lecture," his subject being "Upon Some Hereditary Diseases of the Eye." In 1897 he was President of the Ophthalmic Section of the British Medical Association, and from 1910-12, a Vice-President of the Section of Ophthalmology of the 17th International Medical Congress.



Edward Nettleship.

In 1902 Nettleship, who had already resigned his hospital appointments, relinquished in addition his private practice, and retired to a country seat at Hindhead, Surrey. Here, until his death, he made investigations into the subject of heredity, with especial reference to diseases of the eye. As a result of his services in this extremely difficult department of science, he was elected a Fellow of the Royal Society in 1902. Nettleship died Oct. 30, 1913.

He is said to have been a very brusque, outspoken man, but kind enough at heart, and keenly appreciative of all the excellent qualities of his confrères. He is also said to have been an excellent diagnostician, but "not a brilliant operator." On his retirement from practice a fund was collected for the presentation of a testimonial to his great ability. In accordance with his own desire the money was devoted to the establishment of a medal. This medal is now awarded triennially by the British Ophthalmological Society.—(T. H. S.)

Network, Peritarsal. A set of lymphatics in the eyelid.

Netzhaut. (G.) Retina.

Netzhautbild. (G.) Retinal impression or picture.

Netzhaut-Bildungsfehler. (G.) Retinal malformations.

Netzhaut des Auges. (G.) Choroid.

Netzhauterschütterung. (G.) Commotio retinæ.

Netzhautfernrohr. (G.) Demonstration ophthalmoscope.

Netzhautgefässe. (G.) Retinal vessels.

Netzhautgeschwülste. (G.) Tumors of the retina.

Netzhautstäbchen. (G.) Rods of the retina.

Netzhautzapfen. (G.) Retinal cones.

Neubildung. (G.) A new formation in an organism, the elements of which differ from those of the part in which it is developed; regeneration of tissue; the restoration of a part by a plastic operation.

Neumann's disease. Pemphigus vegetans.

Neuracetin. A proprietary analgesic compound allied to phenacetin.

Neuradynamia. Nervous prostration; depression due to the exhaustion of nerve energy. The name for a group of symptoms resulting from some functional disorder of the nervous system, with severe depression of the vital forces. It is usually due to prolonged and excessive expenditure of energy, and is marked by tendency to fatigue, lack of energy, pain in the back, loss of memory, insomnia, constipation, loss of appetite, etc. (Dorland.)

Neuralgia, Facial. See **Neuralgia of the fifth nerve.**

Neuralgia of the fifth nerve. OCULAR NEURALGIA. TRIGEMINAL, TRIFACIAL NEURALGIA. TIC DOULOUREUX. PROSOPALGIA. Of the many local, clinical varieties of neuralgia the most frequent and by far the most severe is that of the fifth or trigeminal nerve, the largest and most important nerve of common sensation in the body. It is not intended here to define or even outline with detail the entire course of the trigeminal. Suffice it to say that sharply-localized or radiating pain referable to the eyeball or orbit in this disease arises chiefly in the course of the supraorbital branch of the first ophthalmic division or the infraorbital branch of the second superior maxillary division of

this nerve. Intense interest will continue to be felt in tic douloureux so long as the pathogenesis remains obscure and the agonizing pain eludes our complete and permanent control.

Experience with patients suffering from neuralgia of any kind or in any location, quickly leads to the conviction that *relief from pain* is usually the first and urgent need, although search for and removal of the cause (if possible) is a service of more intrinsic value. In the zeal to control pain, causal factors of minor facial neuralgias are apt to be slighted, entirely overlooked or misinterpreted. The teeth, for instance, should receive careful examination and, caries aside, an impacted wisdom tooth, when suspected, should with the help of an X-ray picture not escape detection. Riggs' disease (dental exostosis) is a greatly overestimated cause of neuralgia. The mere possibility of a dental source of aggravation should not lead to the purposeless extraction of nearly all the sound teeth a patient may possess, a fearful penalty to pay without in the least influencing the severe type of trifacial pain. The infections of the accessory nasal sinuses and the antrum of Highmore are occasionally factors in producing neuralgic pains, and when properly treated cause the latter to subside, but sinus enthusiasm among some rhinologists has made possible the correlation of every trigeminal pain with sinus infection, an inference not at all warranted if our positive experience with gasserectomy is to count for anything in determining the ganglion as the pathogenetic source of trifacial neuralgia.

Local irritation from the mouth, nasopharynx, middle ear complications, ocular disease (iritis, glaucoma), and inflammatory foci at a distance capable of producing neuralgic pain must be sought after and intelligently treated as they deserve. Refractive errors are, according to most observers, not a source of neuralgic pain except in psychoneurotic individuals. It is of the utmost importance to apprehend as a common source of minor neuralgic pain the general systemic condition of a patient suffering from malaria, influenza, lues, anemia, the drug toxemias and intestinal autointoxication, and in each instance outline the proper treatment. Neuralgic pains about the face secondary to general disease, such as diabetes and rheumatism, call for the treatment of the underlying disease. Other prolific sources as hysteria and neurasthenia, require the treatment of these conditions.

The numerous measures from time to time adopted to prevail against the pain of trifacial neuralgia include an array of diverse antineuralgic drugs, methods of counter-irritation, nerve stretching, deep infiltrating (nerve deadening) injections, peripheral nerve resection, and in the last analysis, gasserectomy.

Sedatives having less value than anodynes or antineuralgics in the presence of severe pain, neither bromides nor valerian are of much service in this affection. They only suffice to control nervous irritability. Aconite and gelsemium are said to have a selective action on the fifth nerve. The tincture of aconite, gtts. v-xv, or the fluid extract (m. i-ii) may be given for several doses at intervals of one hour each. Starr prefers aconite and calls it the best remedy. The fluid extract of gelsemium (m. ii-iv.), increasing same by one drop each time, may be safely given in moderately severe cases, every three to six hours, until the physiologic effect (heaviness of the upper eyelids) is produced. The fluid extract is to be preferred to the tincture or other preparations, although Horsley contends that tincture of gelsemium, ʒi, given every two hours, is very effective when pushed to produce toxic symptoms, "a feeling of sickness with numbness in the extremities of the fingers."

For the relief of the pain in many mild early cases, the following combination may be used with good success: Ext. gelsemii fld., gtts. i-ii; Ac. arsenos, gr. 1/100-1/30; Antipyrin, gr. iii-vi.; Caff. cit., gr. ss-i; Ft. Caps. d. tal. dos. No. 1: One capsule, to be repeated every two or three hours for three doses, with a full glass of water.

Extract of cannabis indica (gr. ¼-i) is of value. Arsenical preparations (acidi arsenosi, liq. pot. arsenitis) have been used, and latterly sodium cacodylate, gr. ⅛ to ¼, has found favor in the anemic and malnutritional cases, while quinine has been used as an alterative in the non-malarial, and as a specific in the malarial, types. Dana's advocacy of styrchnia hypodermically in increasing to massive doses of gr. 1/50 to gr. 1/5 once daily has received a thorough trial, with, however, somewhat indifferent results. The coal-tar products, headed by antipyrin, have a marked palliative effect on the pain, even in the severer and chronic cases, but must be given in larger doses and oftener than ordinarily (gr. v-xv every two or three hours) to be serviceable. Acetanilid, gr. v, or phenacetin, gr. x, or salipyrin, gr. xv, or salophen, gr. xv, combined with caffein citratis, gr. ii, in each instance given to avoid any depressant action on the heart, is indicated. Of other palliatives, butyl chloral hydrate, gr. v, every hour for four doses, has been highly recommended.

Where arteriosclerosis is a factor, nitroglycerin, gr. 1/100 to gr. 1/50, or nitrite of sodium, gr. ss to i, are of service.

When most remedies fail to relieve, then opium or morphin must be advised, and this is what eventually happens in the majority of the cases. Krause forbids it absolutely because of its habit phase; but

interdiction of this sort is hardly tenable in the presence of an imperative necessity for relief during paroxysms.

In every case of trigeminal neuralgia the general supportive treatment, consisting of full diet—milk, eggs, cod liver oil, beef marrow, tonics, is important. The rest-cure treatment with massage and hydrotherapy may prove necessary.

Castor oil given nightly in ʒss to ʒi has been recommended and has proven serviceable in controlling pain in a number of cases. Its beneficial action, when the laxative effect has worn off, is thought to be due to its nutritive and food values and is therefore of service in anemic and poorly-nourished individuals.

Change of climate should be advised whenever there is provocation, and especially if palliation is disappointing.

Local measures. Blisters and the actual cautery to the "tender points" on the face diminish pain, but incur facial blemishes. The ethyl chloride spray refrigerates the skin and gives better temporary relief. Liniments, lotions and salves have a very transient effect, but may be tried.

Electro-therapy, on the whole fails to accomplish anything, although galvanism (weak) in early cases is recommended.

Intra- or perineural injections. 1. A few drops of cocain solution (½ to 4 per cent.) injected into the foraminal exits of the supra- and infraorbital branches on the face gives prompt but only transient relief. 2. Osmic acid (1 per cent. in glycerine and water) (Bennett; Murphy) injected in like manner as cocain, with a view to destroying the pathological sensory irritability of the nerve, is a method now quite obsolete. 3. Alcohol (2 c. c. in ascending strengths, 70 to 90 per cent.), has been injected into the large divisions of the fifth nerve at their basal exits from the skull, the foramina ovale and rotundum and, for the first division, the orbit (method of Levy and Baudouin). The results in twenty-two of the writer's cases in a total of sixty-two injections by this method have given much satisfaction. The chance for cure in a permanent sense from a single injection is not good, but complete cessation of pain for a period of from two to ten months results from one or more injections.

With gasserectomy expedient only in desperate cases as a last resort, deep alcoholic injections are deserving of much consideration and attended with successful and prolonged palliation.

Surgical treatment. To be considered are section and resection of the peripheral nerve trunks, nerve stretching, divulsion, extirpation of the Gasserian ganglion, division of the sensory root of the fifth nerve above the ganglion.

Gasserectomy is to be suggested as the final intervention, with the prospect of a cure, but the gravity of the operation gives rise to hesitancy on the part of the patient, and the surgical difficulties encountered cause most operators to be diffident in this undertaking.

Neuralgia, Ocular. See **Neuralgia of the fifth nerve.**

Neuralgin. A proprietary mixture of caffein, antifebrin, and sodium salicylate: an anti-neuralgic and anti-rheumatic. Dose, 8-45 gr. (0.5-3 gm.).

Neuramebimeter. An instrument for measuring the reaction-time of the nerves.

Neurasthenia, Ocular relations of. Whether Beard's definition of nervous exhaustion for what was once ironically called the American disease stands approved today, or the condition is regarded as one in which an excess of irritability and debility are the prominent features, matters less than the fact that neurasthenia is acknowledged as a clinical entity the world over. That the visual apparatus shares in the so-called general irritable weakness characteristic of the disease, witness the references to asthenopia, ocular muscle insufficiencies, anomalies of the visual field and neurasthenic pupillary phenomena. Defects in our present special economic and industrial system are so directly responsible for the development of the neurasthenic state that the mention of prophylaxis must include a rather unavailing tirade against existing conditions. It must suffice to hint that neurotic individuals should not unduly expose themselves to either the physical or mental strain incidental to the struggle for existence.

The general treatment includes for the average case a rational allowance of physical exercise, rest, sleep, diet, baths, massage, and interesting, mild mental preoccupation.

In the more aggravated cases a partial rest cure at home or a full Weir Mitchell rest plan combined with isolation is indicated. For the details of this well-known and now universally adopted method of treating advanced neurasthenics, the reader is referred to any of the recent works on therapy, or the small but complete book entitled "*Fat and Blood*," by Weir Mitchell.

Not only should the physical condition of the patient at rest in bed be conserved, but the mental state also impressed by the judicious and constant application of psychotherapy.

Drugs of the tonic order, such as iron, strychnin and arsenic; sedatives, like bromides; hypnotics, such as sulfonal, trional, veronal and isopral, are to be given with great care and in very conservative doses when indicated. Rest and nourishment, as a rule, will accomplish

more without than with medicines. Visits to spas, the seashore or the mountains are beneficial.

It is of utmost importance in all cases to determine the causal factors in the production of the neurasthenic state, if these are present. See, also, **Hysteria,** p. 6123, Vol. VIII; as well as **Copiopia,** p. 3305, Vol. V, of this *Encyclopedia.*

Neurasthenic asthenopia. See **Copiopia,** p. 3305, Vol. V, of this *Encyclopedia.*

Neurataxia. NEURATAXY. Neurasthenia.

Neuratrophia. NEURATROPHY. Impaired nutrition of the nerves or of the nervous system.

Neuraxis. An axis-cylinder; also the cerebrospinal axis.

Neuraxon. Any axis-cylinder process.

Neure. A nerve-cell with all its processes; a neuron.

Neurectasia. NEURECTASIS. NEURECTASY. The surgical stretching of a nerve.

Neurectomy, Optico-ciliary. An operation in which portions of the optic nerve and of the ciliary nerve are exsected, the other steps being identical with those in optico-ciliary neurotomy. In Meyer's operation the tendons of the external and internal recti are divided, also the two oblique muscles. The fibrous capsule of the globe is then completely detached, and the optic and ciliary nerves are divided and exsected. See p. 4456, Vol. VI of this *Encyclopedia.*

Neurepithelium. 1. The epithelium forming the nerve terminations of the organ of Corti and the retina. 2. The epiblast, which becomes the cerebrospinal axis.

Neurergic. Pertaining to or dependent on nerve action.

Neurexairesis. Evulsion or tearing out of a nerve.

Neuriatry. The treatment of nervous diseases.

Neuricity. The specific energy peculiar to the nervous system.

Neurilemma. The sheath of a nerve-fibre; also the epineurium.

Neurin. A highly poisonous alkaloid, produced by the chemical decomposition of protagon, and occurring in putrefying meat and in the putrefaction by which certain esculent fungi are rendered poisonous. Its action is physiologically intermediate between that of muscarine and curare, producing dilated pupils, profuse secretions, acceleration followed by paralysis of respiration, and general convulsions preceding death. Atropin antagonizes its effect on the heart and the glandular system only. See **Toxic amblyopia.**

Neurit. NEURITE. Any axis-cylinder process from a nerve cell: a neuron.

Neurite multipla. (It.) Multiple neuritis.

Neurite ottica. (It.) Optic neuritis.

Neuritic dots. A name given to any of the minute white or yellow dots seen in the fundus. These are sometimes discovered in eyes apparently normal. They may be either "crick" dots or any of the other punctate conditions observed by the ophthalmoscope.

Neuritis axialis. One of the synonyms of retrobulbar neuritis.

Neuritis, Descending. NEURITIS OPTICA DESCENDENS. An optic nerve inflammation which begins somewhere in the trunk of the nerve, usually within the orbit, involves the sheath especially, and extends downward toward the intra-ocular end of the nerve. The name was given by von Graefe to the form of the optic neuritis that accompanies meningitis and shows itself in choked disk.

Neuritis, Multiple, Ocular relations of. NEURITIS MULTIPLEX. POLYNEURITIS. Multiple neuritis *per se* is not so much a disease entity as it is a symptom-complex capable of great variation, depending upon the cause and the particular peripheral nerve groups involved.

It is produced by a great variety of causes of which chronic alcoholism is by far the most common, but other poisons, such as arsenic, lead, phosphorus, mercury, ergot, sulphide of copper, coal-tar products, illuminating gas (carbon-monoxide), furnish additional causes, grouped together as toxic forms of exogenous origin. In a second group are the cases developing subsequent to acute infections, diphtheria, typhoid, grippe, scarlet fever, measles, pertussis, smallpox, sepsis; to chronic infections, some of which are beri-beri, tuberculosis, syphilis and leprosy. Another group of cases is chiefly of auto-toxic origin, and arises in the course of diabetes, gout, pregnancy and the puerperium, senility, general cachexia and intestinal toxemia. Some authors refer to Landry's paralysis as idiopathic polyneuritis and consider beri-beri as a disease *sui generis*.

Multiple neuritis causes some signs and symptoms that are quite constant in nearly every case, no matter what the cause. The motor and sensory involvement is multiple, bilateral and symmetrical; paralysis is of the flaccid type; the tendon reflexes are lost in the affected extremities; trophic disturbances are present, as is also the electrical reaction of degeneration. These are the qualifying symptoms of a degenerative lesion of the lower set (peripheral) of motor neurons. The clinical picture of multiple neuritis, depending upon its many causes, varies too widely to admit of extended comment here. The fact, however, that the cranial nerves may become involved in the course of multiple neuritis and affect the eye by occasionally causing ocular palsies and very rarely an optic neuritis, is some warrant for considering, in brief, the disease and its treatment. The *vision* may

be reduced. The pupils have been observed to be dilated, contracted, or irregular. Loss of light-reflex has been reported, but it is probably transient. The accommodation is usually disturbed in diphtheritic neuritis. In the latter disease diplopia occurs in 10 per cent. of cases, and less frequently in alcoholic neuritis. In the latter, nystagmus, or nystagmiform movements, have been observed. The motor nerves of the eye may be singly involved, as in ptosis, but there may be complete ophthalmoplegia, which is usually nuclear in origin. Optic neuritis, contracted fields, and color-scotoma may complete the eye-picture.

Striving to reduce the extraneous sources of infection and toxic poisons to their minimum will not always suffice to prevent the occurrence of multiple neuritis, for the reason that such effort does not take into account or seek to eliminate individual susceptibility, which plays a rôle of considerable importance in this particular affection. We are in no position to satisfactorily explain why nerve tissue should attract one poison with disastrous result to itself and remain unaffected in the presence of another, or why one substance acting upon a mixed peripheral nerve elects to disturb sensation much more than motion, or *vice versa*, or why alcohol prefers to paralyze the legs and lead the arms, again with a selective exemption in typical cases of the supinator longus. These are and perhaps must remain inexplicable phenomena that repose deeply somewhere in our neuropathic constitutions and lie there in wait as predisposing causes to defeat some of our best efforts at effectual prevention. It is to be hoped that the use of a universal antitoxin (Ehrlich) against sepsis in many of its forms, or a specific serumtherapy against certain of the acute infectious diseases, will tend to eliminate post-infectious types of neuritis.

The direct causal factors referred to in a preceding paragraph are amenable to considerable control and especial attention should be paid to the convalescence from infections, various dyscrasias, diatheses, and the chronic forms of gastro-intestinal auto-intoxication.

Since it is only the chronic alcoholic who is predisposed to polyneuritis, timely advice as to the danger of continuous indulgence is much in order, and this applies quite as appropriately to the women as to the men, for many cases of neuritis are traceable to their unobtrusive excesses in this direction.

Arsenical and lead poisoning may in a large degree be averted by the proper supervision of industrials having to do with these preparations. The careful and repeated examination of patients taking arsenic, particularly Fowler's solution, will by the prompt recognition of physiologic and toxic action of this drug avert the disaster of arsenical neuritis.

Resourcefulness in methods of active elimination is important in combating all forms of toxemia. The kidneys should be flushed; the circulation neutralized by the absorption per rectum of large quantities of normal saline solution. Sweating and brisk catharsis are also valuable adjuncts for this purpose.

When neuritic symptoms appear, the indication for absolute rest is established and becomes imperative. The dangers of over-treating must be avoided. It is quite enough to secure immobilization and warmth at this stage of the disease. All undue efforts, such as attend eating, the voiding of urine and passage of solid feces should be restricted as much as possible. Pain will be greatly relieved by rest and relaxation, but analgesics and coal-tar derivatives will in most cases have to be administered. The number of old reliable and newer preparations is large enough to facilitate a choice, and antipyrin, phenacetin, acetanilid, salicylates, salophen, salipyrin, pyramidon, singly or in combination, may be used to advantage. Any undue depressant action likely to follow the exhibition of any coal-tar preparation is best avoided by combining with each dose camphor monobromate and caffein citrate, each gr. i. If the pain is too intense to succumb to these remedies, codein sulphate, gr. ½ to 1, and even morphin sulphate, gr. ¼ to ½, will be found necessary.

An ample, rich, nutritious diet is indicated, and if, as in diphtheritic forms, swallowing is difficult (pharyngeal palsy), the feedings should be given by means of a stomach tube. Edinger emphasizes the value of milk, butter, buttermilk, bacon and a diet otherwise rich in fats. Moderate and uniform heat is of benefit in controlling pain, stimulating surface temperature and capillary circulation. In the acute stage Oppenheim recommends that a diaphoretic treatment, consisting of hot drinks, hot packs, superheated air, etc., be given the patient for from one to two hours daily. Counter-irritants are now little used. Local anesthetics and rubifacients are to be discouraged.

Electricity is generally applied with but little understanding and discretion in neuritic disturbances. It should only be used after the subsidence of pain or when the acute symptoms have run their course. Too often the neuritis is greatly aggravated by the premature and ill-advised use of the electrical current. So as not to add irritation to pre-existing irritability of the nerves, a measured, weak, interrupted galvanic current should be applied for a short time each day to the impaired muscles, with a view to gradually increasing the strength when nutritional and functional improvement warrant it. Massage, too, should be reserved for the late reactionary stage and active move-

ments and gymnastics withheld until returning strength indicates their daily use.

In the acute stages care should be exercised to avoid every semblance of pressure through weight of the bed-clothes, and such malpositions of the extremities as wrist or foot-drop (extensor paralysis) should receive enough support from splints, sandbags and sundry devices to overcome as much as possible the contractures likely to develop. For the late, neglected deformities of high degree, orthopedic measures will be found necessary.

A tonic, supportive treatment after the acute stage is passed is of importance and the administration of elixir of iron, quinin and strychnin is indicated after meals. Strychnin hypodermically, gr. 1/60 to gr. 1/20, three times daily; arsenic in small doses; oleum morrhuæ; hypophosphites, etc., will prove of undoubted value in building up the tissues. With judicious treatment and close attention to details and to the needs of the patient as they arise, the results of treatment in multiple neuritis are most gratifying.—(D. H.)

For further consideration of the ocular symptoms, see the subhead *Multiple neuritis*, under the caption, **Neurology of the eye.**

Neuritis, Optic. See **Optic neuritis**; as well as **Neurology of the eye.**

Neuritis optica chronica. A chronic form of optic neuritis, slow in onset and gradually progressive; usually due to some blood dyscrasia or of sympathetic origin.

Neuritis optica fulminans. A form of optic neuritis in which loss of vision comes on with great rapidity.

Neuritis optica hereditaria. See **Leber's disease,** p. 584, Vol. VIII of this *Encyclopedia.*

Neuritis optica interstitialis. Optic neuritis characterized by cellular infiltration and hypertrophy of the fibres of the connective tissue framework of the optic-nerve trunk. These swell enormously, while the nerve fibres themselves are but little or not at all affected. It is usually accompanied by perineuritis.

Neuritis optica intraocularis. Optic neuritis within the eyeball; choked disc.

Neuritis optica medullaris. Optic neuritis characterized by marked hyperemia of the medullary fibres, with small hemorrhages, degeneration of these fibres, and subsequently hypertrophy of the connective tissue fibres of the framework.

Neuritis optica retrobulbaris. An inflammation of the trunk of the optic nerve behind the eyeball; characterized by a sudden loss of sight in one or both eyes, without at first any ophthalmoscopic evidence of

disease, but followed later by either a marked ischemia of the disc and retina or by signs of "choked disc."

Neuritis optica sympathica. Inflammation of the optic nerve as the result of sympathetic disease occurs in *two clinical forms*, of which by far the commoner is the form associated with uveal disease of the usual type. It is the opinion of most observers that this occurs far more frequently than is known to be the case, but that the plastic exudation in the anterior and vitreous chambers, to say nothing of the intolerance of the eye to light, makes thorough inspection so difficult that the condition is often overlooked. As Edgar Thomson *(Jour. Am. Med. Assn.*, Sept. 21, 1912), says enough cases have been observed, however, to establish the fact that the condition occurs not infrequently, and in the patients who have recovered from sympathetic uveitis evidences of atrophy have frequently been noted.

A much rarer form is the one unassociated with uveal inflammation, which may appear as a simple neuritis, usually of low degree, or a neuroretinitis with exudates in the macula or around the disk, somewhat resembling the deposits of albuminuric retinitis. See **Sympathetic ophthalmia.**

Neuritis optica syphilitica. Simple papillitis due to the presence of a gumma in the cranial cavity; a syphilitic optic neuritis affecting the trunk of the nerve.

Neuritis optici transversa. A form of retrobulbar neuritis.

Neuritis, Orbital optic. See **Retrobulbar neuritis.**

Neuritis, Retrobulbar. See **Retrobulbar neuritis.**

Neuritis, Spurious. PSEUDO-OPTIC NEURITIS. PSEUDONEURITIS PROMINENS. PSEUDO-PAPILLEDEMA. Beard *(Semiology and Diagnosis*, p. 217) has drawn and described a remarkable example of this condition, presenting normal fields and good central vision, which he regards as congenital and which the average observer would certainly set down as a case of true optic neuritis. He points out that in recent years a number of cases have been recorded of an anomalous physiologic condition which resembles choked disc to an extraordinary degree. So strong has been the resemblance in some instances that the diagnosis has, for a time, been left in abeyance. The chief points of differentiation are that there is not the lardaceous enlargement of the papilla; that, aside from their tortuosity, there is absolutely no change in the appearance of the trunks of the retinal veins; that there is no enlargement of Mariotte's blind spot, which is characteristic of choked disc; the visibility of the optic nerve-fibres is not enhanced; and there is absence of any associated symptoms, such as intermittent severe headaches, sudden vomiting, vertigo, cramps, etc., though enough of these may be present

merely to involve the diagnosis. The hyperopia at the summit of the papilla in the case from which his drawing was made was thirteen dioptres, while that of the macula was only four. Vision with the correcting glass was subnormal. There was frequent severe headache and vertigo. These were relieved by glasses that corrected the hyperopia. It may be here remarked that many patients with choked disc do not consult the physician because of visual troubles, but to obtain relief from violent headache and other symptoms.

Loring and Graefe attribute the indistinctness of the borders of the disc in these cases to a superabundance of connective tissue at the papilla. With this view Uhthoff virtually agrees, his explanation being that it is due to a want of diaphaneity in the nerve-fibre layer.

Neuritis, Trench. A toxic condition observed in soldiers who have passed long periods in the unsanitary surroundings of trench life. The ocular involvements are chiefly edema of the retina, ocular hemorrhages and the formation of white retinal plaques. The blood pressure was found to be high in bad cases.

Neurochorioretinitis. Inflammation of the optic nerve, choroid, and retina.

Neurochoroiditis. Inflammation of the choroid coat and optic nerve.

Neurocyte. A nerve-cell of any kind.

Neurocytoma. A tumor consisting of cells which tend to differentiate into nerve-cells.

Neurodealgia. (Obs.) Excessive sensibility of the retina.

Neurodeatrophy. An obsolete name for atrophy of the retina.

Neuroderm. The ectoderm or epiblast.

Neurodes. Neuroid; as a neurode, the retina.

Neurodictyitis. (Obs.) Optic neuritis with retinitis.

Neuroepithelioma. See **Glioma of the retina,** p. 5582, Vol. VII of this *Encyclopedia*.

Neuroepithelium. A specialized epithelium forming the perceptive elements of the organs of special sense, as the rods and cones of the retina.

Neurofibril. The supposed conducting element of the nerve-fibres and nerve-cells, forming a delicate network in the nerve-cells, passing out of their processes and ending in or around a muscle or sense-cell.

Neurofibroma, Ocular. In addition to the matter on p. 5019, Vol. VII of this *Encyclopedia*, it may be added here that most authors make no distinction between ocular neurofibroma and ocular neuroma.

The upper lid is a favorite situation for neurofibromatosis. There is a characteristic hypertrophy of the nerves, also a condition of lymph stasis, and fibromatosis of the subcutaneous tissues.

In so-called multiple neurofibromatosis, other parts of the ocular apparatus may be involved. Fehr *(Cent. f. p. Augenh.,* Vol. 37, p. 233, 1913) reports four cases of this character. The first two presented respectively bilateral optic atrophy and subsiding papilledema, and were the only ones showing ocular changes out of five cases of general neurofibromatosis referred from the skin clinic of the Virchow hospital. In another case several operations, the technic of which is described, were rendered necessary on the eye involved in the general disease from the fact that the second eye was lost from panophthalmitis of independent origin. The body was covered with hundreds of soft fibromata. The palpebral fissure was greatly displaced down and out, the skin of the left brow, of the bridge of the nose, and of the left eyelids being transformed into a soft flabby pendulous tumor, containing knotty thickenings. The eye itself was normal.

Fehr's fourth case is of exceptional character. For fifteen years a man 38 years old had been affected by multiple neurofibromatosis. Violent headaches, migrainous attacks, and slight visual disturbance were followed by the fundus appearance of optic neuritis with venous stasis, and the patient became firmly persuaded that he was developing an intracranial tumor. But the other eye was entirely normal, and he was assured that the condition was limited to the orbit. The vision of the eye became almost lost, and the patient insisted on an exploratory Krönlein operation, which however revealed nothing abnormal. Some months later enucleation of the eye became necessary in consequence of hemorrhagic glaucoma. Fehr feels that the ocular changes must have been due to compression of the central retinal vein by a minute orbital neurofibroma.

The microscopic findings in a case of buphthalmos accompanying neurofibromatosis are reported by Murakami (*Klin. Monats. f. Augenh.,* Oct., 1913). There was more or less pronounced fibromatous involvement of all branches of the ciliary nerves, both within and without the eyeball; a condition which harmonizes with the reports of several other writers. The buphthalmos is attributed to an increase of secretion secondary to disturbance of circulation, depending not merely upon the nerve changes, but also upon connective tissue proliferation affecting the blood and lymph vessels. See, also, **Neuroma.**

Neurofil. A network of processes springing from the beginning of the axis-cylinder and surrounding the cell.

Neuroglia. The supporting structure of nervous tissue. It consists of a fine web of tissue made up of modified ectodermic elements, in which are enclosed the peculiar branched cells known as *glia-cells.* It is called *bind-web* also.

Neuroglioma. Glioma containing nerve-cells; a tumor made up of neurogliar tissue.

Neurography. The anatomy, physiology, pathology, etc., of the nervous system.

Neurohypophysis. The *pars nervosa* or main part of the posterior lobe of the pituitary body.

Neuroinoma. Neurofibroma.

Neurolemma. An old name for the retina.

Neurology of the eye. Although the relations, normal and pathological, of the oculo-nervous system are mostly covered in individual sections and sub-sections of this *Encyclopedia,* it is considered wise to emphasize here the importance of certain additional facts relating to the eye, plus the brain, the spinal cord, and the extracranial nerves. The reader is, as a part of this study, especially referred to such headings as **Intracranial organs of vision,** p. 6547, Vol. IX; **Hemicerebrum,** p. 5766, Vol. VIII; **Optic nerve,** p. 395, Vol. I; as well as p. 5965, Vol. VIII; **Hemiopia,** p. 5766, Vol. VIII; **Chiasma,** p. 2039, Vol. III; **Tabes dorsalis; Pituitary body: Choked disc,** p. 2074, Vol. III; **Brain tumor,** p. 1273, Vol. II; **Cerebrospinal meningitis,** p. 1974, Vol. III; **Brain abscess,** p. 1267, Vol. II (and other **Brain** captions); **Meningitis,** p. 7641, Vol. X; **Meningocele,** p. 7643, Vol. X; **Idiocy,** p. 6138, Vol. VIII; **Imbecility,** p. 6176, Vol. VIII; **Dementia præcox,** p. 3811, Vol. V; **Encephalitis,** p. 4305, Vol. VI; **Cerebellum, Tumors of the,** p. 1969, Vol. III; as well as all other **Brain; Cerebrospinal; Nerve; Spinal** and **Cerebro-headings;** also, the neurologic sub-sections in such rubrics as **Perimetry; Comparative anatomy of the eye; Medical ophthalmoscopy** (in particular); **Congenital anomalies; Military surgery of the eye; Toxic amblyopia; General diseases,** as well as in **Familial affections** and **Heredity in ophthalmology.**

So intimately connected are many, indeed most, of the ocular tissues with the central and peripheral nervous systems that almost every visual organ, every ophthalmic disease, indeed, every oculo-therapeutic measure exhibits a neurological aspect. This fact has been commented on to a greater or less length under the captions just mentioned, and it only remains to refer, as will now be done in alphabetical order, to certain eye affections that are *particularly* related to the cerebrum and its extensions.

The literature of the subject as a whole is well covered by Wilbrand and Saenger's *Neurologie des Auges,* and by Posey and Spiller's *The Eye and the Nervous System,* to which the reader is also referred.

Acute ascending paralysis. Landry's paralysis. Eye symptoms

in this disease are uncommon because the affection is usually fatal before the nuclei of the eye muscles are involved. Abducens paralysis has been noted and a few cases are on record in which ptosis was present. Pupillary symptoms are rare although slow reaction to light may be present. According to Kapper, ocular motor paralysis has appeared in exceptional cases leading to diplopia and accommodation paresis. See, also, p. 7007, Vol. IX of this *Encyclopedia*.

Alcoholic poisoning. In acute alcoholism paresis of the external ocular muscles may occur. Most frequently there develops an insufficiency of the interni with diplopia. Gudden found in several cases of acute alcoholic poisoning dilation of the pupil with loss of light reaction. Myosis, mydriasis or slow and unequal reaction of the pupil may be present. While complete blindness has been observed, visual phenomena are infrequent in occurrence, and with rare exception are transient in character. Interference with the visual fields is almost never noted.

In chronic alcoholism paresis of the ocular muscles may occur and is usually bilateral, the abducens being most often affected. External ophthalmoplegia with intact inner musculature occurs more rarely.

Nystagmoid movements, especially accompanying paresis of the eye muscles were often seen by Uhthoff, while real nystagmus is very rare.

Amblyopia is of frequent occurrence. An early symptom is dimness of vision, which is frequently less marked in somewhat subdued light. There is present a central scotoma for colors and for white. While impairment of sight usually comes on gradually, the amblyopia may develop rapidly and there may be a sudden accentuation of symptoms attendant upon renewed excesses or upon fatigue. It is difficult in some cases to differentiate the diminution or loss of light reaction from cases due to accompanying liver affection.

The ophthalmoscopic examination reveals in the beginning, even when vision is already much disturbed, a normal eye ground, though in some cases there may be hyperemia of the papilla. Later atrophy of a part of the papilla may be observed, due to a partial retrobulbar neuritis. The process usually remains limited to the papillo-macular bundle of fibres. A complete optic atrophy is very rare.

Chronic sub-acute retrobulbar neuritis in persons addicted to alcoholic beverages is not uncommon. See, also, **Toxic amblyopia**.

Amaurotic family idiocy. Arrested cerebral development. Infantile cerebral degeneration. Agenesis corticalis. See p. 287, Vol. I; and 5155, Vol. VII of this *Encyclopedia*.

Beri-beri. This disease endemic in the tropics probably from fish poisoning, is a form of multiple neuritis. The ocular symptoms mani-

fest themselves as loss of vision and paralyses of the muscles, both the internal and external systems being involved. Paralysis of accommodation is especially frequent with involvement of the sphincter pupillæ. Visual disturbances progressing to blindness have been reported. Ophthalmoscopic changes may or may not be visible. An optic neuritis or an atrophy of the optic nerve may be present. With amelioration of the general disease, the eye disturbances usually clear up even when the blindness has lasted several weeks. Amnesic aphasia and word-blindness have followed the loss of vision. See, also, p. 936, Vol. II of this *Encyclopedia*.

Progressive bulbar paralysis. Progressive glosso-pharyngo-labial paralysis. According to Cassirer no case of true progressive bulbar paralysis has been observed in which there were definite changes in the nuclei of the oculomotor and trochlear nerves. Oppenheim (*Text Book of Nervous Diseases*, p. 1006), however, in a rare, atypical case, noted an extension of the paralysis to the ocular muscles, first the levator palpebraris superior, then the abducens. According to Ball (*Modern Ophthalmology*, p. 785) the eye symptoms occasionally seen in pseudo-bulbar paralysis of cerebral origin afford a point of differentiation between this disease and a true bulbar paralysis. See, also, p. 1325, Vol. II of this *Encyclopedia*.

Cerebrospinal meningitis. As Axenfeld (*Encyklopädie der Augenheilkunde*) points out, the eye changes of this serious disease may be divided into the following groups:

1. Conjunctival and orbital. Conjunctivitis may arise in the beginning of the disease, or later in consequence of insufficient lid closure. It shows nothing characteristic and bacteriologically has not as yet been worked out. A chemosis of the conjunctiva bulbi is usually a passing sign of metastatic meningitis ophthalmia. If it persists, however, and accompanies exophthalmos it is due to a progression of the intra-cranial inflammation into the orbital fatty tissue through the orbital fissure. (A typical septic thrombosis of the cavernous sinus such as arises especially in otitic brain complications, has as yet not been observed in primary meningitis.)

2. Motor nerves. The preference of the meningeal exudate for the base of the brain explains the frequency and variety of irritations and palsies of the external muscles and of the pupil. With recovery of the meningitis the palsies are still capable of retrogression even after a long time.

3. Trigeminus. There may be disturbances of sensation and keratitis, but the latter is more often due to lagophthalmus than to neuroparalytic changes. Such corneal conditions may lead to panophthal-

mitis. It may be that the keratitis begins as herpes fibrilis, as herpes labialis is known to be frequently present in meningitis.

4. Visual paths and globe. (a) Pressure of the exudate upon the base, especially in the neighborhood of the bony canal, may bring about double blindness, with or without the ophthalmoscopic picture of optic neuritis. Such pressure blindness may recover after a lapse of several months, while in other cases it leads to optic atrophy. A much rarer form of this blindness is due to pressure upon the visual centers. This has been proved in single cases, but the prognosis is uncertain and depends upon the complicating atrophy.

(b) Outside of the intracranial compressions of the visual fibres the inflammation may extend along the sheaths downwards to the papilla as perineuritis descendens, ophthalmoscopically showing the picture of an optic neuritis at times with very marked changes in blood vessels. The visual disturbance is variable, as is also the ultimate outcome even in cases of recovery of the causative disease. On the whole the optic neuritis is less frequent in suppurative primary epidemic meningitis than in tuberculous, for the reason that the thick exudate of the former obstructs the access to the sheaths more easily. It is frequent in the otitic and other transmitted meningitis. The neuritis is usually toxic in character for the reason that the exciting cause of the meningitis can pass through the lamina cribrosa only with difficulty. A true choked disc with marked swelling is therefore very rare in pure meningitis.

(c) The so-called irido-choroiditis, better, suppurative meningitic ophthalmitis, is metastatic. Until now no proof has been advanced that this condition is a continuation or extension of the infection through the nerve sheaths, while there is abundant evidence of its being metastatic in origin.

The clinical course of this form of metastatic ophthalmitis (which usually sets in at the height of the disease) is peculiar in that it seldom develops into perforative panophthalmitis, and late phthisis bulbi is rare. In some cases vision has been somewhat restored.

It is surprising, that of those cases with meningitic ophthalmia complications very few have died, so that the prognosis for life itself in these cases is relatively good.

As the exciting agent in this "meningitic-ophthalmia" we have first of all to consider the diplococcus intracellularis meningitis (Weichselbaum) and the Fraenkel-Weichselbaum pneumococcus. See, also, p. 1974, Vol. III; as well as p. 7642, Vol. X of this *Encyclopedia*.

Congenital spastic rigidity of the limbs. Little's disease. A concomitant strabismus is present in from 25 to 30 per cent. of the cases

of congenital or early acquired spastic paralysis, and forms the most important of the ocular symptoms of this disease. It is supposed to be caused by tonic spasms of the ocular muscles, although cases with paralysis have been reported. Nystagmus and atrophy of the optic nerve occur, but very rarely.

Dementia præcox. The ocular changes in dementia præcox show nothing characteristic of the disease itself, though the various changes often described as found in this disease bear close resemblance to those found in the fundus of patients suffering from chronic intoxication. Ocular palsies are encountered only coincidentally, and can generally be referred to a concomitant affection, such as syphilis or trauma.

The pupils may be dilated but are equal and the pupillary reflex is present for both light and accommodation; though not infrequently the extent of both is less than in normal individuals. The sensory pupil reflex excited by stimulation of the skin of the neck, is frequently absent, as well as is the cortical reflex of Haab, but this defect may be referred to failure of attention on the part of the patient rather than to inhibition through a central or peripheral nervous affection. The activity of the reflex varies with the activity of the patient, being less during the stage of profound stupor. Especially is this true of the catatonic form of the disease. See, further, p. 3811, Vol. V of this *Encyclopedia.*

Diphtheritic paralysis. See p. 3113, Vol. IV; also p. 3998, Vol. VI of this *Encyclopedia.*

Encephalitis. In addition to the matter on p. 4305, Vol. VI of this *Encyclopedia,* attention is here drawn to the divisions by L. Bruns (*Encyklopädie der Augenheilkunde*) of this disease and their accompanying ocular affections.

There are two general types. (1) Disseminated type. (a) Encephalomyelitis disseminata acuta, in which the whole brain and cord are interspersed with a large number of very small inflammatory foci. (2) Circumscribed type. (a) Polioencephalitis superior hemorrhagica (Wernicke) which attacks especially the region of the corpora quadragemina. (b) Polioencephalitis inferior or bulbar myelitis (pons and medulla oblongata) which frequently accompanies the superior to form a polioencephalitis superior et inferior, or with spinal involvement to form polioencephalomyelitis. (c) Acute primary hemorrhagic encephalitis, which attacks especially the cerebrum.

The boundaries between the disseminate form and the more localized forms are not distinct. There are all sorts of overlapping and combinations between the solitary forms; or they may spread over wide areas of the central nervous system, as in polioencephalomyelitis.

Optic atrophy occurs frequently in all forms of encephalitis, either alone or in association with other cranial nerve palsies or sometimes even with true multiple peripheral neuritis.

The acute disseminated encephalomyelitis (Leyden's acute ataxia) occurs especially in children during or after acute infectious diseases, small-pox, measles, scarlet fever, chicken-pox. It presents the picture of a severe multiple sclerosis which arises acutely, sometimes over night. Optic neuritis is frequently present and almost always nystagmic tremor, usually associated with tremor of the head. Both symptoms disappear quickly, as the disease on the whole has a very good prognosis.

In Wernicke's polioencephalitis acuta superior hemorrhagica the eye muscle symptoms are conspicuous and are usually the first to appear. They consist of double-sided, usually not entirely symmetrical, nuclear, oculomuscular palsies. Contrary to earlier opinion the levator palpebræ and the intraocular muscles are often involved. Optic neuritis is practically the rule. Other symptoms are headache, anesthesias, lethargy and, less frequently, ataxia. The disease is found especially in alcoholics, but also after sulphuric acid poisonings.

In twenty cases Wilbrand and Saenger note the following facts of importance with reference to the ocular conditions. In nine cases there was ptosis of varying degree. In all cases excepting two, in which no observation of the condition of the muscles was made, the ocular muscles were variously involved, giving rise to more or less immobility of the eyes with accompanying diplegia, nystagmus, and strabismus. The pupils showed varying reactions to light from normal to complete immobility. Practically no observations were made on the power of accommodation because of the constant palsy of the external muscles. Ophthalmoscopic examination in a few instances showed changes of hyperemia, unusual pallor of parts of the disc, and occasionally papillitis. In general the ocular condition showed no tendency to conform to any one type.

In pure polioencephalitis inferior (which is infrequent) the eye symptoms are limited to abducens and facial, especially orbicularis, palsies; later, trigeminal symptoms. Paresis of associated movements (conjugate paresis) on one side or both sides may also arise. Palsies of the other bulbar nerves and of the extremities may also occur.

An encephalitis pontis of one side may give a very definite clinical picture of hemiplegia alternans, while conjugate paresis to the left, left facial and trigeminal paralyses, anesthesias, ataxia, and paralysis of the right extremities allow a definite localizing diagnosis to be made.

More frequent than this pure form is the combined superior and inferior forms, in which the oculomotor is also involved.

Asthenic bulbar paralysis is also a chronic polioencephalomyelitis. Here the optic neuritis is wanting, although paralyses of the eye muscles are found in various combinations. Ptosis is especially frequent, while the intraocular muscles are intact. An isolated paralysis of the orbicularis oculi is frequently found in the distribution of the facial nerve. The paralyses vary greatly in intensity. They may be entirely wanting after a rest and become manifest only after use, for instance, ptosis may be absent upon awakening in the morning and markedly present later in the day.

While many of the cases recover, death is not infrequent and occurs at times quite suddenly from asphyxiation.

Cerebral encephalitis is frequently accompanied by optic neuritis, and isolated paralyses of the eye muscles are observed. The motor region of the cerebrum appears to be the place of predilection when no special eye symptoms are found, except possibly a conjugate deviation. The visual centers in the subcortical and cortical regions may become involved, especially in the occipital lobes, when hemianopsia may appear.

Epilepsy. See p. 4484, Vol. VI of this *Encyclopedia.*

Exophthalmic goitre. See p. 901, Vol. II, as well as p. 4805, Vol. VI of this *Encyclopedia.*

Facial paralysis. See p. 5136, Vol. VII of this *Encyclopedia.*

Friederich's disease. Hereditary ataxia. The nature and pathology of this affection are still in doubt. As far as ocular symptoms are concerned, it was emphasized by Friederich himself that the disease is characterized by a complete absence of any abnormalities or disturbances in the eyes, with the exception of a certain form of nystagmus. This nystagmus, which is sometimes called pseudo-nystagmus or atactic nystagmus, consists of irregular twitchings which occur only when the eyes are fixed on a moving object, especially in the horizontal direction. When the eyes are at rest, or when they are fixed at a point in the sagittal plane, they are, as a rule, perfectly quiet.

A number of cases have been reported which showed ocular symptoms, and differed also in other respects from those described by Friederich. Under the name "Heredoataxie cerebelleuse," (hereditary cerebellar ataxis) Pierre Marie described a clinical picture which had, in common with Friederich's disease, the hereditary character, but differed from it in the eye symptoms and in the condition of the parellar reflex, which was increased here but absent in Friederich's disease. Muscular palsies, loss of pupillary reflex, disturbances of vision, various

affections of the optic nerve were comparatively frequent in this disease. So indefinite has been the differentiation between these two conditions that it is necessary to regard some cases as of a "mixed type." See, also, p. 662, Vol. I; as well as p. 5161, Vol. VII of this *Encyclopedia*.

Hydrocephalus chronicus. Chronic hydrocephalus appears in either the congenital or acquired form. In the congenital form the eye symptoms most frequently met with are choked disc or a neuritic atrophy with binocular blindness. The position of the eye-ball is frequently characteristic. The globe is pushed downward to the extreme, so that practically the whole upper sclera is exposed and the lower corneal border disappears beneath the lower lid. It has been assumed that this abnormal position was mechanical, through the arching forward of the upper orbital roof, but Henoch has observed cases which showed the dropping of the eye-balls without any displacement of the bones of the roof of the orbit. He assumed the displacement downward to be due to the paralysis of the muscles which normally elevate the eyes, that is, a partial paralysis of the oculo-motor nerve. Occasionally divergent strabismus, ptosis and even nystagmus have been noticed.

The diagnosis in the well-developed type of hydrocephalic form of the head from the rhachitic skull, is sometimes made possible only by the absence of eye symptoms in the rhachitic cases.

In acquired chronic hydrocephalus the most important eye symptoms are choked disc with transition into atrophy, bi-temporal hemianopsia due to pressure of the arched forward floor of the third vertricle on the chiasma, and eye muscle palsies which are relatively frequent. The oculomotor is most often affected. The pupillary reaction is often disturbed and a nystagmic jerking is not infrequent. The trigeminal and the facial nerves are occasionally involved. There is a moderate exophthalmus.

When the eye and cranial symptoms of chronic acquired hydrocephalus are associated with headaches and vomiting, slow pulse, tonic convulsions, vertigo, wavering gait and fine tremors of the arms and hands, the diagnosis from cerebellar tumor is difficult or impossible. Probably some of the symptoms of cerebellar tumor are due to the internal hydrocephalus present. Oppenheim states there are only two factors which serve as guides to the differential diagnosis. One is that the hydrocephalus depends in many cases upon some congenital condition which is shown by an abnormal size and shape of the skull. The second is the occurrence of remission and intermission of years

duration which is, at least, most unusual in cerebral tumor. See, also, p. 6076, Vol. VIII of this *Encyclopedia.*

Hypochondriasis. There are no ocular symptoms characteristic of hypochondriasis. On the other hand, some perfectly trivial ocular complaint may excite the morbid fancy of the patient, for example, a mild conjunctivitis or a recurring hyperemia of the conjunctiva may cause him to go from one consulting room to the other, hoping for relief and believing in all manner of evil consequences. The same is true if he once becomes conscious of the shadows which the formed elements of the vitreous cast upon the retina and to which are given the name muscæ volitantes. They are not caused by hypochondriasis nor are they a symptom in one sense, but they are a condition which may greatly aggravate the mental disturbance. Long-standing hypochondriasis may produce contraction of the visual field and phenomena which have been described in general terms as fatigue fields, or exhaustion fields, such as occur in neurasthenic patients.

A matter of some importance is the effect of presbyopia on these patients. Neglected presbyopia, or a failure of accommodation, for which no adequate relief is sought, even before the presbyopic age, is frequently the cause of hypochondriasis and mild forms of melancholia. The patients cannot be made to understand that their symptoms arise from the physiological failure of accommodative power, and believe that they have some disease which later will eventuate in blindness. The irritating inconvenience of oncoming and increasing presbyopia doubtless aggravates these mental conditions under many circumstances. That eye-strain in general may produce hypochondriasis is well known.

Infantile cerebral paralysis. The main symptoms of this uncertain lesion may be classified as hemiplegias and diplegias. The eye disturbances are more frequent in diplegia, but are not infrequent in hemiplegia, the commonest being strabismus and nystagmus, the latter generally of the rotary type. In a fair percentage of cases, however, especially in those of the familial form, either one- or double-sided optic atrophy is found. This may lead to complete blindness, but more often the vision is only diminished. The atrophy is the result either of a direct or primary inflammation of the optic nerve, or it is a descending process. Definite double descending optic nerve atrophy may develop in children with lesions of the occipital lobe. In the hemiplegic type of palsy the atrophy may be associated with homonymous, total or quadrant hemianopsia. See, also, p. 5155, Vol. VII of this *Encyclopedia.*

Injuries to the spinal cord. T. H. Weisenberg, (*The Eye and*

Nervous System) divides the ocular phenomena following traumatic lesions of the spinal cord, into three classes: First, changes in the optic nerve; second, sympathetic phenomena; third, pupillary changes.

As to the first category, Allbutt observed slight haziness of the optic disc and engorgment of the retinal veins. He stated that these changes did not occur except in chronic cases, and only in the course of a few weeks or months, and that the higher the lesion, the more likely they are to occur. It is probable that at times changes in the disc occur, but these are mild and temporary, and therefore frequent and early ophthalmoscopical examinations are necessary to detect the condition. No ocular disturbances occur in any case in which the lesion is below the second dorsal segment. A few cases are on record where lesions below this area produced changes in the fundus, but a closer examination always showed involvement of the cervical cord. We are led to believe, therefore, that in some cases of injury to the spinal cord we may have a low grade optic neuritis, and that this only occurs if the cervical cord is involved.

As to signs of sympathetic involvement, the cervical sympathetic is quite frequently affected in traumatic lesions of the spinal cord. The classical symptoms of irritation of the cervical sympathetic are enlargement of the pupil, widening of the palpebral angle, a slight exophthalmus, delayed descent of the upper lid on looking downwards, paleness of the face and increase of the sweat secretion. Paralysis of the cervical sympathetic produces a small pupil, narrowing of the palpebral angle, a slight enophthalmus, a warmth or coldness of the face, and hyperidrosis or anidrosis. Intraocular tension is somewhat diminished. We however rarely see all of these symptoms in a lesion of the sympathetic. This is partially explained by the different centers in the spinal cord for the oculi pupillary and the vasomotor, trophic and secretory functions. In the majority of instances the only sympathetic phenomena observed in traumatic lesions of the cervical cord are myosis and sometimes a narrowing of the palpebral fissure. These symptoms are produced not only if the lesion is in the eighth cervical and first dorsal segments, but also if the lesion is higher.

As to pupillary changes, in a number of instances of injury to the upper cervical cord the pupils have been found irresponsive to light while the reaction to accommodation and convergence was normal, in other words the Argyll Robertson phenomenon.

Intoxication amblyopia. Intoxication, or toxic, amblyopia denotes a diminution of vision brought about by some form of poison. The important eye signs attending this numerous class of causative agents

are treated under individual heads, as well as on p. 303, Vol. I of this *Encyclopedia.* See, also, **Toxic amblyopia,** the major heading.

Kowakow's psychosis. In this disease there is not infrequently paralysis of the extraocular muscles, as well as miosis, pupillar rigidity or diminished reaction. Slight pallor of the temporal side of the disc has also been noted.

Lead-poisoning. Plumbism, saturnism. The eye symptoms constitute one form of *intoxication amblyopia.* Affections of the eyes are found in 1.2 per cent. of lead-poisoning cases. The ocular manifestations are varied and in no case characteristic of the intoxication. The diagnosis may be made only when other symptoms of lead-poisoning are present.

As Posey and Spiller (*The Eye and the Nervous System*) point out, the chronic form of plumbism may give rise to both amblyopia and disturbances of muscle innervation. The amblyopia presents typical central scotoma. At the same time there may be concentric contraction of the fields for form and colors. Not infrequently the scotoma assumes the form of a hemianopsia. Actual organic changes, such as optic neuritis, neuroretinitis, optic atrophy, or changes in the vessels (perivasculitis) may supervene. Ophthalmoscopic appearances vary from negative findings or mere vascularity of the nerve head, to the definite organic changes. The visual manifestations of chronic lead-poisoning may consist of transient amblyopia due to the anesthetic effect of lead upon the optic nerve and retina, or of a permanent amblyopia due to retrobulbar neuritis. The latter may terminate in neuritis, neuroretinitis or a permanent atrophy. Finally, amblyopia may be due to a vasculitis of the retinal vessels.

De Schweinitz states that chronic lead-poisoning is a well recognized cause of paralysis of the external ocular muscles. According to Elschnig there are two varieties of ocular palsies occurring in the course of lead intoxication. First, palsy of central origin, associated with vertigo, headache, and vomiting, the cases terminating in rapid death; second, palsies of peripheral origin. The latter are more frequent, less rapid in their onset, and are less fatal. Ptosis, strabismus and diplopia may be present. The third nerve may be involved in its entirety, or the paralysis may affect only one of its branches. Isolated pupillary and accommodation disturbances do not frequently come under observation. See, also, **Toxic amblyopia.**

Meningitis. In *simple* meningitis there may be external inflammatory symptoms such as conjunctivitis and swelling of the lids, and the cornea may be infiltrated. The pupils are at first usually contracted and later dilated, or they may be immovable. Impairment or com-

plete abolition of the reflex reaction of the pupil to light is observed in from 10 to 15 per cent. of the cases. The difference in the size of the pupils is about as frequent. The ocular muscles are rarely affected in this condition though strabismus may follow involvement of the third nerve.

In the *epidemic form of cerebro-spinal meningitis* involvement of the muscles of the eyes are met with in from 13 to 15 per cent. of the cases. The paresis of the abducens is the most common, while that of the oculomotorius is less frequent. Pupillary disturbances are rarely met with; extreme dilation of the pupil with loss of its reactivity is far more frequent in the tuberculous than in the epidemic form of meningitis.

In *meningitis of purulent, otitic origin* the nerve supply of the abducens is the most frequently affected of all the ocular muscles. Next in frequency comes the facial nerve, while involvement of the other nerves is rare. Little can be learned from the behavior of the pupils. On the whole, it may be said that ophthalmoscopic changes are not very common in otitic meningitis. If a typical choked disc follows otitic disease, it usually indicates other intracranial complications, such as abscess of the brain or sinus phlebitis.

In the *epidemic form of meningitis* optic neuritis takes first place among the ocular symptoms. After a few days the optic disc may become hazy and the vessels engorged. The papillitis may be severe, the disc becoming obscured and subsequently atrophied. Blindness may ensue.

In the *tuberculous form of meningitis*, optic neuritis is the most common ocular symptom. It is present in from 25 to 30 per cent. of the cases. A prominent choked disc is not uncommon. Descending neuritis with great loss of vision and slight changes in the fundus on the other hand is rare. Simple hyperemia of the papilla and hemorrhages into the retina are infrequent and have little diagnostic value. When it is suspected that a cerebral hemorrhage or hematoma of the dura is present in a case of *pachymengitis interna hemorrhagica* we look for a choked disc or an optic neuritis, for it has been ascertained that in such hemorrhages the blood enters the sheath of the optic nerve and excites the symptom of engorgment of the papilla. The diagnostic value of choked disc in only one eye is particularly great, for such a condition is very rare in other central lesions as tumor of the brain, abscess, hydrocephalus, and even in fracture of the base of the skull and laceration of the middle meningial artery. Retinal hemorrhages are also found in many of these cases. In about 10 per cent. of cases of tuberculous meningitis we meet with discrete tubercules in the

choroid. These small, yellowish-gray, distinctly prominent and usually sharply-defined foci in the choroid have a predilection for the region of the posterior pole. They may occur with a neuritis or independently; and they are much more common in general miliary tuberculosis, where they are found in nearly half the cases. Taking all these lesions of the optic nerves and choroid together, neuritis, choked disc, hyperemia, descending neuritis and tubercule of the choroid, we find, according to Uhthoff, pathological changes in 49 per cent. of the cases of tuberculous meningitis.

Inflammation of the orbit is very rarely met with. Neuroparalytic keratitis is no more apt to occur in epidemic than in tuberculous meningitis, but the two diseases may sometimes be differentiated by the fact that a metastatic ophthalmia takes place in about 5 per cent. of the cases of epidemic cerebro-spinal meningitis either in the early or late stage of the disease. This sympathetic ophthalmia is of hematogenous metastatic origin and may run a very mild course.

Hemianopic defects in the visual field are scarcely ever observed in this disease.

Multiple neuritis. Polyneuritis. Disturbance of sight is not uncommon in multiple neuritis, and when it does occur, is generally in the nature of a central scotoma, especially for colors. Blindness has been reported in a number of instances, but in none of these is there an uncomplicated history.

One of the best accounts of the ocular relations of the various forms of this affection will be found in Posey and Spiller's *The Eye and the Nervous System.*

Alcoholic multiple neuritis. The optic nerve is very seldom involved in alcoholic multiple neuritis. Pathological pallor of the temporal side of the disc has been described, especially by Uhthoff (*Arch. of Ophthalm.*, Vols. XXXII and XXXIII) who examined a thousand alcoholics and discovered eye changes in 139. He found by histological examination a retrobulbar neuritis in six of these instances. It cannot be assumed, however, that the pathological paling of the tem-either condition can occur without the other being present.

Optic neuritis is an exceedingly rare occurrence; it may be well-marked in both optic nerves or be limited to one. It is usually mild in character, but may be very severe. The neuritis comes on generally late, and in most instances disappears as the disease improves. In most of the recorded cases, a part or all of the third, sixth and seventh nerves are also involved. The pupils are usually not affected in alcoholic multiple neuritis, but a difference in size is not unusual, and the Argyll Robertson phenomenon has been reported in rare instances.

Uhthoff in an examination of one thousand alcoholics found a difference in the size of the pupil in sixty cases. In twenty-five there was, besides, a slow reaction of the pupil to light, and in ten instances there was a reflex pupillary rigidity, the reaction to accommodation being nearly always preserved. Oppenheim records reflex iridoplegia in both pupils, and in one eye accommodation was lost.

The eye muscles are not often involved. Unilateral external rectus palsy is the most common form of ocular paralysis, but both abducens nerves may be paralyzed. The seventh nerve is at times involved, generally in association with the sixth. One or both oculomotor nerves may be involved. More often the outer musculature of the oculomotor nerve alone is diseased, causing ptosis, while the inner musculature remains free, iridic motion (and accommodation) not being disturbed.

There may be present no pathological changes either in peripheral ocular nerves or in their central connections; or alterations only in the peripheral ocular nerves. There may be changes only in the gray matter of the third ventricle and the quadrant of Sylvius; and, finally, a combination of the degenerative lesions of the peripheral ocular nerves with the encephalitic process of Wernicke.

Clinically, it is almost impossible to differentiate between these pathological processes. A rapid onset with a bilateral ophthalmoplegia in which both the outer and inner musculature are involved, with a possible accompanying optic neuritis, may point to an acute polioencephalitis.

Nystagmus has been observed repeatedly in alcoholic polyneuritis, especially on lateral deviation. Inasmuch as nystagmus has not been noted in direct fixation, this is probably a pseudo-nystagmus due to partial abducens palsy.

Lead multiple neuritis. In cases where lead poisoning causes intracranial symptoms, termed *lead encephalopathy*, we may have paralysis of the cranial nerves, the vocal cords and the laryngeal muscles. All of the ocular nerves, the third, fourth and sixth may be involved alone or in combination. Either optic neuritis or atrophy may occur.

Optic neuritis alone has been observed repeatedly in the course of chronic lead-poisoning. Goldscheider has called attention to the interesting fact that optic neuritis may occur alone in conditions which lead to polyneuritis, as, for instance, in the infectious diseases and in the different metallic poisonings. It is probable, however, that in these cases the optic neuritis is not a precursor of multiple neuritis but is a manifestation of a cerebral disease. Changes in the size of the pupils with loss of the light reflex have been observed, but there are also present encephalic symptoms. Paralysis of the eye muscles without

involvement of the other cranial nerves is not very common in lead polyneuritis. See *Lead poisoning*, in this section.

Multiple neuritis due to other metallic poisons, such as mercury, has also been known to produce multiple neuritis, but these instances are rare. The form of polyneuritis due to carbon disulphide is extremely uncommon and little is known of its pathology, as observations are lacking. Workers in vulcanized rubber are especially prone to multiple neuritis. Ocular phenomena are common and consist as a rule of alterations in the visual fields, especially for colors. Amblyopia is a fairly constant symptom. Scotoma, either large or small, is found in some cases and pupillary rigidity and even nystagmus have been recorded.

Illuminating gas may produce symptoms which resemble multiple neuritis. Involvement of the different cranial nerves is not uncommon. Cases are recorded in which the third, fourth, fifth, sixth and seventh nerves were paralyzed, wholly or in part. The paralysis persists only for a short time and disappears as the general symptoms improve. Blindness has also been recorded.

Sulphonal and trional neuritis from long usage of these drugs has been reported. Erbsloh records an instance of a man of forty who had taken two grammes of sulphonal daily for five days and developed symptoms of polyneuritis. The right pupil was larger than the left, the left abducens nerve was paralyzed and he had hallucinations of sight. At the necropsy the peripheral nerves were found degenerated. Dillingham also records a ptosis that lasted two days.

Multiple neuritis due to infectious diseases. Such infectious diseases as erysipelas, typhoid fever, pneumonia, measles, scarlet fever, gonorrhea, influenza and rheumatism may cause multiple neuritis, but these instances are necessarily rare. Eye symptoms in them are exceedingly uncommon. Fuchs, however, records a mild grade of optic neuritis with pallor of the temporal side of the disc in a typhoid subject with polyneuritis. Microscopical examination showed a retrobulbar neuritis. It is probable that the infection did not directly cause the optic neuritis.

Influenza (lagrippe) may cause optic neuritis and paralysis of the different ocular muscles as an accompaniment of multiple neuritis. Wilbrand and Saenger have reported thirteen cases in which the third nerve was involved. In twelve there was accommodation paralysis, and in one the iris was paralyzed. Ptosis occurred eight times; in five it was bilateral, in three unilateral.

In malarial neuritis, one instance of bilateral abducens palsy was noted by Strachan.

In the multiple neuritis of *beri beri* eye symptoms occur, but they have been insufficiently studied. Kessler examined the eye grounds in sixty cases and found a narrowing of the retinal arteries, paling of the papilla and in a large number of cases the edges of the disc blurred. It is probable, however, that these changes in the disc are due to the general nutritional disturbance which is extreme, and not to the multiple neuritis. Disturbance of vision, even complete blindness, may occur.

In *leprous multiple neuritis* there may be involvement of the eyeball. In the nodular form the lepromata may invade the conjunctiva, the cornea, the anterior chamber of the eyeball, the iris, the ciliary body, or they may originate in these parts, in which event they ulcerate and finally destroy the sight in both eyes.

In the neuritic type, owing to the atrophy of the facial muscles, it may be impossible to close the eyes and there may be eversion of the lower eyelid. The upper eyelids may droop. At first there is a conjunctivitis with lachrymation, but later in the disease there may be ulceration of the cornea, and finally complete destruction of the eyeball. See **Leprosy,** p. 7426, Vol. X of this *Encyclopedia.*

Tuberculous multiple neuritis is rare, and eye symptoms are recorded only in very few cases. Among these Fuchs records optic neuritis and nystagmus, and Rosenheim pupillary differences. The vagus, facial and phrenic nerves have been affected but not the ocular muscles.

According to Oppenheim (*Text Book of Nervous Diseases*, p. 510) there is no doubt of the existence of a multiple neuritis due to the syphilotoxic poison. Cases are recorded in which all the cranial nerves, with the exception of the first, were involved either wholly or in part.

Senile polyneuritis is rare. Schlesinger mentions a case in which there was a transient diplopia and sensory disturbance in the distribution of the fifth nerve. There can be no doubt of the occasional occurrence of ocular palsies due to the neuritis, and caused by the pressure of the sclerosed basal arteries.

Carcinomatous multiple neuritis, due to carcinomatous intoxication does not differ from the other forms of polyneuritis due to toxic causes. In a case of Miuras there was a slight optic neuritis with an absolute, central scotoma. There was also nystagmus on upward and lateral deviation, and diplopia. These symptoms appeared several weeks before death, and persisted. The microscopical examination by Uhthoff failed to show any cause for the optic neuritis. The various peripheral nerves, as well as the orbital parts of the third and sixth nerves, showed degeneration. The slight swelling of the papillæ was attributed to the broadening of the nerve fibres in the upper layers.

Polyneuritis of primary neurotic atrophy. Because of lack of sufficient pathological evidence, confusion still exists as to the cause of this disease. It occurs in families and is distinguished by atrophy, developing in the distal portions of the extremities. The reflexes are absent and there are few sensory disturbances. Pathologically, in the few cases recorded, alterations have been found in the peripheral nerves and muscles; also in the nerve cells of the anterior horn of the spinal cord.

Optic atrophy accompanying this disease has been recorded by Ballet, Rose Vixisli, and A. Gordon. It is difficult to explain the occurrence of the optic atrophy and the involvement of the ocular muscles. It is probable, however, that we have here conditions foreign to the disease itself. See, also, **Neuritis, Multiple.**

Myasthenia gravis. Erb's disease. Asthenic bulbar paralysis. According to E. W. Taylor (*The Eye and the Nervous System*) the disease is insidious in onset, and characterized by weakness and rapid tiring of the muscles. Ptosis and diplegia are very early symptoms in nearly half the cases; also weakness of the legs and arms, or involvement of the facial, hypoglossal and accessory nerves. As the disease develops, the usual characteristic picture is double ptosis, double facial paresis, paralysis of the bulbar nerves, associated with dyspnea, and general bodily weakness. Among these symptoms the ocular palsies occupy probably the most conspicuous place, and of individual symptoms ptosis is the most frequent, occurring sooner or later in more than eighty-five per cent. of all cases. Various external muscles of the eye are also frequently involved, but the internal muscles governing the pupil are very rarely included in the muscular weakness. Wilbrand and Saenger (*Neurologie des Auges*, 1899) report one case of weakness of the sphincter iridis and ciliary muscles. In order of frequency of occurrence there are found bilateral ptosis, disturbance in the distribution of the facial nerve, involvement of the orbicularis, diplegia, ophthalmoplegia externa, unilateral ptosis, and weakness of the sphincter iridis and ciliary muscles. See the major caption, **Myasthenia gravis**; also, p. 1326, Vol. II; and p. 4505, Vol. VI of this *Encyclopedia.*

Myelitis. Neuromyélite optique aigue. Ophthalmoneuromyélite. Both acute and subacute myelitis may be accompanied by inflammation of the optic nerve, but in the majority of cases the disease first manifests itself in a rapid diminution of vision. One or both eyes may be affected and the loss of sight may go on to total blindness. A marked improvement may take place, but complete recovery of vision is rare. In about one half of the cases the blindness is lasting. It is

not always necessary to have subjective symptoms of loss of vision, and the optic nerve may remain normal in appearance throughout the entire course of the disease. Usually, however, the symptoms are preceded or accompanied by pain in the orbit and in the frontal region of the affected side. The pain is increased by pressure on the globe or by extreme rotation of the eyeball. The pain is supposed to be due to an inflammation of the optic nerve sheath or to a periostitis of the optic foramen.

In the majority of cases the optic neuritis precedes the myelitis by a period of time varying from a few days to several months. The symptoms may come on together, or the onset of the optic neuritis may follow the myelitis.

The condition of the pupil varies with the location of the lesion. In all cases of amblyopia the pupils are wider than normal and the reaction to light is lost. If the myelitis involves the cervical cord, especially the eighth cervical and the first dorsal segment, there may be contraction of the pupil, narrowing of the palpebral fissure and enophthalmos, due to paralysis of the cervical sympathetic. Involvement of the medulla oblongata may lead to abducens palsy, also to ophthalmoplegia with other bulbar symptoms.

Disturbances of the fields of vision and of the color-sense may be seen in the beginning of the disease as a concentric contraction either for form and color or for color only. Less often sector defects are present, which rarely may take the temporal hemianopic form. A central scotoma may be present associated with slight or marked peripheral defects.

Ophthalmoscopic examination may reveal an optic neuritis or a choked disc with tortuosity of the vessels. The retina is usually not involved. Frequently the examination is negative or there may be present only a slight temporal pallor. In about one half the cases the neuritis passes over into a temporal pallor or general atrophy of the disc. It is questionable whether such an atrophy in myelitis may occur without a preceding inflammatory appearance; nevertheless in about one half the cases only an atrophic condition of the nerve has been noted. Both optic nerves are involved in the majority of instances.

The disease is met with in children and adults, the ages varying from 12 to 60 years. Males are more often affected than females, in the proportion of about three to one. No common cause has been discovered, which will apply to the majority of cases. Syphilis has been the most frequently mentioned etiologic factor. Shock, worry, cold, gazing at an eclipse of the sun, influenza, complicated miscar-

riage and oral sepsis have all been mentioned as possible causes in individual cases. Katz expresses the opinion that the cause of the disease will be found in some poison as yet unknown, which simultaneously affects the spinal cord and the optic nerves.

Charles Goulden (*Ophthalmic Review,* July, 1914) reports a case of myelitis occurring in a man aged 62, in which the eye symptoms preceded the general symptoms by six days. He also believes in a common (toxic) causation of the spinal and ocular lesions, and concludes that: (a) (as shown by 52 cases) the eye symptoms were the first to appear 36 times, the spinal cord symptoms 10 times; simultaneous appearances of eye and cord symptoms 3 times; not stated 3 times; (b) the clinical courses of the affection of the optic nerves and spinal cord run parallel; thus an acute myelitis is associated with an acute optic neuritis and a subacute myelitis with a subacute optic neuritis; (c) there is a decided similarity of the pathological findings in the optic nerves and spinal cord; (d) there is a markedly disseminate character of the lesions in the various parts of the spinal cord; (e) there is evidence that a toxic agent has been brought by the blood stream, as shown by the engorgement of vessels with blood, that the destruction of nerve fibres is perivascular and that the perivascular spaces are filled with round cells.

Analogous to this connection are the papillitis of disseminated sclerosis and the optic atrophy of chronic spinal cord disease, more especially tabes dorsalis. For these a common origin is accepted, and there seems no reason to deny a similar pathologic community in cases of myelitis with optic neuritis. See, also, **Myelitis, Ocular relations of,** in this volume of the *Encyclopedia.*

Neurasthenia. In addition to the matter under **Neurasthenia** in this *Encyclopedia* it may be said here of the *eye symptoms* that the phenomena of irritation consist in trembling of the orbicularis upon command to close the lids (Rosenbach's phenomenon) fibrillary twitchings of the orbicularis palpebrarum, scintillating scotoma and photophobia. The fatigue phenomena consist of the symptoms of nervous asthenopia such as immediate fatigue in doing near work, early blurring of objects, pain in the neighborhood of the eyes, ciliary tenderness, deep orbital pain and headache. However, transient blurring of objects and darkness before the eyes may come on without the association of strain for near work. The visual field appears normal in neurasthenia if fatigue is avoided in the examination. Otherwise there is a contraction of the field which is to be considered as fatigue phenomenon. The central color perception is not disturbed; on the

other hand the peripheral color fields show irregularities, the borders being constricted and intercrossed.

Inequality of the pupils and hippus may be present in neurasthenia. All the various symptoms are, however, to be considered as neurasthenic in origin only when the most careful examination eliminates every possible anatomical change which may prove the functional disturbances to have an anatomic basis. It must also be remembered that neurasthenia seldom exists alone, but is either associated with hysteria or some other asthenic disease.

Ophthalmic migraine. See p. 7694, Vol. X of this *Encyclopedia.*

Ophthalmoplegia chronica. This affection is usually progressive and forms a part of a more general process, as for example, tabes or dementia paralytica. It is frequently associated with progressive bulbo-pontine degeneration of motor nuclei and at times of spinal cord lesions of similar character.

Its development is slow and its course long. Although varying widely in detail, the disease begins usually with diplegia or ptosis, followed by a very gradual extension of the palsy to the external ocular muscles of both eyes; the accommodative mechanism and the levator palpebræ superior are often spared. Later the internal muscles may be involved, or in other cases they may be affected from the beginning. The progressive involvement of the muscles points always toward nuclear degeneration as a cause, easily explained by the complicated anatomical arrangement of the nucleus of the third nerve. As the process continues the eyeball may ultimately become wholly immovable, and the levator palpebræ and orbicularis oculi also may be involved. In rare cases the disease is checked when the ocular paralysis is complete. It is, however, usual for the degeneration to extend to other nuclei, with an ultimately fatal outcome. (Posey and Spiller's *The Eye and Nervous Diseases.*)

Paralysis agitans. Tension and rigidity occur in the ocular muscles in this disease, though far less frequently than one would expect. The sphincter is never affected; the pupils have been found normal in reaction and the optic nerve always remains unimpaired. The rigidity is apt to show itself in the orbicularis, making the opening and closing of the eyes very slow and sluggish. There may be partial ptosis. The movements of the eyeballs are sometimes somewhat retarded. A few cases have been observed where there was great difficulty in convergence; also spasm of accommodation has been described. Complete ophthalmoplegia has been reported.

Paralyzing vertigo. Gerlier's disease. See p. 5369, Vol. VII of this *Encyclopedia.*

Paresis. General paralysis. Brain softening. As pointed out by Dercum (Posey and Spiller's *Eye and Nervous Diseases*), the ocular phenomena of paresis consist in disturbances which may involve all parts of the visual apparatus, the muscles (internal and external), the optic nerve, and the fundus. The most common of the ocular phenomena are those which relate to the pupil. One of the earliest phenomena usually observed is that of inequality of the pupils. It must, in this connection, be remembered that a difference in the size of the pupils may occur physiologically, but the difference is usually slight. If, however, this inequality is associated with sluggishness to light reaction, or if the pupils, being equal, react differently to light, the finding is suggestive of incipient paresis. Moreover, impairment of the consensual light reaction may be the first symptom of a pupillary disorder and it is of the same value as a difference of reaction of the two pupils. Miosis, even if slight, in conjunction with other symptoms, is very significant. Distinct miosis is a symptom of unquestioned value. Exceptionally it occurs in the very early stages of this disease. The Argyll Robertson pupil has rarely been observed in the early stages of paresis. Changes in the fundus of the eye may also be noted early, though such changes are exceptional. Optic atrophy has been known to precede the mental symptoms. It is unusual, however, in practice, to meet with early cases of paresis in which some ocular changes, even though slight, cannot be found.

If a systematic study be made of the eyes in paresis when the disease is well established, the following phenomena are noted. First; there is very frequently observed an inequality of the pupils; they may be irregular, that is, slightly oval or ovoid, or the circumference may be irregular from various modifications of shape. These modifications do not, however, lead to gross deformities; still, they can be readily observed. Miosis is also a symptom frequently observed in advanced paresis. The opposite condition, mydriasis, likewise occurs, but is decidedly less frequent than miosis.

Next in importance are changes in the light reflex. This is impaired or lost upon one or both sides in a very large number of cases.

De Montyel made an exhaustive study of light reflexes in paresis and came to the following conclusions: First, the light reflex is more frequently abnormal than normal. Second, exaggeration of the reflex is exceptional. Third, there is only a slight difference in frequency of the diminished and the lost reflex. Fourth, changes in the reflexes are identical on the two sides; only exceptionally is the reflex lost on one side and normal on the other. Fifth, in the first stage of the disease the normal reflex is more frequently present than the abnormal,

while the reflex is more often abnormal in the second and third periods. Sixth, exaggeration and unequal changes on the two sides are always present in the initial stages of the disease; the frequency of loss of the reflex is proportionate to the progress of the disease. Diminution of it is more frequent than loss during the first period; the proportion is about equal in the second, and reversed in the third period. Seventh, the reflex is abnormal in one-quarter of the remissions. Eighth, exaggeration is seen only in the expansive and mixed forms. Loss of the reflex prevails over diminution in the demented form; only in that form are both eyes unequally affected. Ninth, an abnormal reflex is always noted in the traumatic cases. Tenth, at all ages, the abnormal reflex is more frequent than the normal; however, abnormality of the light reflex is especially noted in extreme ages, especially in the younger cases. Eleventh, in the first and second periods the reflex is more affected when the motor symptoms are more pronounced. Absence of the consensual light reflex is met with in nearly half the cases. The reaction to accommodation, as in tabes, is preserved long after the light reflex is lost. However, it is sooner or later involved. The more advanced the case, other things being equal, the more likely is loss or impairment of accommodation to be present.

Changes in the eye ground with progressive amblyopia and amaurosis may be noted in paresis. However, as compared with tabes, such changes are relatively infrequent. White or gray atrophy or segmental pallor of the disc is frequently found.

Disturbances of the visual fields may occur in paresis, but they are not common. This is especially true of marked disturbances. Contractures, however, may be noted. Palsies and other motor disturbances are quite secondary in importance to the other ocular phenomena of paresis, but are relatively infrequent and inconstant.

Paranoia. Pupillary immobility is rarely found in this condition. Absence of light reflex is also rare, but it is more frequent than pupillary immobility. Pupil deformity may be present. Ocular phenomena are quite constantly absent. This is true not only of the pupillary reactions, but also of the fundus. Conditions of depression and exaltation do not furnish corresponding appearances of the fundus.

Paralysis of the brachial plexus. Narrowing of the pupil and of the palpebral fissure may occur if the first dorsal roots are involved, either in the intervertebral foramen, or before their separation from the main trunk. In the lower-arm type of paralysis, in which the eighth cervical and first dorsal roots are diseased, we always have these oculopupillary symptoms.

In disease of the fifth and sixth cervical roots in the intervertebral

foramen, oculo-pupillary symptoms may occur. This can be explained only by the accidental involvement of the same branches of the first dorsal root, or by a lesion of the sympathetic fibres in the spinal cord.

Acute anterior poliomyelitis. Acute atrophic spinal paralysis. Infantile spinal paralysis. The eye symptoms include paralysis of the extrinsic muscles, involving either a single muscle or all the external musculature; ptosis, either unilateral or bilateral; nystagmus, and optic atrophy. While the paralysis is usually unilateral a few cases of bilateral abducens paralysis have been reported and (rarely) bilateral external ophthalmoplegia has been observed.

Paralysis of the abducens is the most common single lesion, but it may set in as a result of multiple lesions. According to Uhthoff the facial and abducens are the nerves usually affected, the oculomotor being rarely implicated. Of 49 cases of poliomyelitis examined by Medin oculomotor paralysis occurred once, another form of external ophthalmoplegia once, and facial palsy several times. Wiekman observed a combination of abducens, oculomotor and bilateral trochlear paralysis. He states that in most of the cases of unilateral ophthalmoplegia the levator palpebralis is not involved. Posey and Swindells (*Ophthalmic Record*, p. 609, Dec., 1916) report a case of paralysis of the left sixth and seventh nerves, there being slight left lagophthalmos with epiphora and incomplete closure of the palpebral fissure, with diminution in the external rotary power of the left eye, and a convergent strabismus of 35°. They also report a case with complete external ophthalmoplegia that disappeared after several weeks.

The etiology of the ocular palsies is still in doubt. Uhthoff claims they are dependent upon cerebral, medullar and meningeal complications, and are not found in uncomplicated cases of anterior poliomyelitis. Weisenburg (discussing paper by Posey and Swindells) believes they are due to nuclear or intramedullary lesions and are not of meningeal origin, because of the absence of anterior and posterior root palsies, none of which has been observed in this disease.

Ptosis has been observed alone or in combination with other palsies. Posey and Swindells report a case of uncomplicated double ptosis occurring in a child, aged 5, who had suffered an attack of infantile paralysis six weeks previously.

Nystagmus has been observed in a few cases.

Implication of the optic nerve in acute anterior poliomyelitis is exceedingly rare. Uhthoff (Graefe-Saemisch *Handbuch*, Vol. X, Pt. 1-2, p. 308) says the literature contains no mention of optic nerve lesions in these cases. However, Posey and Swindells (*loco cit.*)

report a case of atrophy of both optic nerves with paralysis of the left abducens and refer to an observation of Tedeschi of a case which exhibited total amaurosis and left optic nerve atrophy. Posey thought the optic atrophy in his case to be due to a complicating meningitis, although the atrophy was not of the variety usually observed following a descending inflammation of the optic nerve such as is common in meningitis. It may have developed primarily by the action of toxins generated by the disease upon the nerve trunks themselves. Weisenburg is of the opinion that the optic atrophy found in infantile paralysis is either the result of a toxemia or of a nuclear lesion.

Primary lateral sclerosis. As a rule there are no eye symptoms in primary lateral sclerosis; occasionally, however, optic atrophy like that seen in tabes is observed.

Posterio-lateral sclerosis. Rigidity of the pupil to light is unusual, but has been described. It may be said that pupillary changes occur in syphilitic cases. Optic nerve atrophy is rare, although it has been described in a few cases. Usually there is no involvement of the extra-ocular muscles, though nystagmus has been recorded.

Pernicious anemia. Eye symptoms are rare. In the later stages of the affection the pupils have been found unequal, and in one instance there was a slight bilateral ptosis and a marked miosis due to lymphatic involvement. In a few instances reflex iridoplegia has been reported. Nystagmus has also been observed. Optic neuritis may occur, giving the ocular picture of albuminuric retinitis. See, also, p. 420, Vol. I of this *Encyclopedia.*

Pseudobulbar paralysis of cerebral origin. This affection usually has no eye symptoms. When present they consist of optic neuritis, optic nerve atrophy, and impossible or difficult voluntary closure of the lids, while reflex closure is normal; also while voluntary movements of the eyeball to the side, or upward and downward are difficult, the patient can follow an object with his eyes. This latter condition is also called Wernicke's pseudo-ophthalmoplegia. See, also, p. 1326, Vol. II of this *Encyclopedia.*

Blepharospasm. Spasm of the lids. Spastic closure of the lids manifests itself either as a twitching or as a contraction of the orbicularis muscle, and may be an isolated symptom or a part of a general facial spasm.

The spasm may be *tonic* (continued complete or incomplete closure), *clonic* (manifesting itself in abnormal twitchings) or *mixed.* In the last-named class the tonic spasm is associated with an occasional marked twitching, or a temporary closure that alternates with clonic twitchings.

The mildest type of the disease consists of fibrillary twitchings in the palpebral portion of the orbicularis, though a spasm of the corrugator supercilii and often of the frontalis may accompany a marked lid spasm.

Tonic lid spasm is usually caused by an inflammation of the eye itself, especially of the cornea, or by the presence of a foreign body. More remote causes may be found in the teeth, the nose, or irritation of the trigeminal, either in its intra- or extra-cranial portion. Functional tonic lid spasm is frequently a manifestation of hysteria. After recovery from facial paralysis certain facial muscle movements, such as the act of laughing, may excite contracture of the orbicularis. This form of blepharospasm accompanying inflammation of the eyes of children may continue for weeks or months and be followed by an amblyopia which, however, clears up after the elimination of the causal lesion.

Clonic lid spasm is of milder character, although it may have the same etiology as the tonic form. It is, however, usually binocular, while tonic spasm is often monocular, or distinctly more severe on one side. Catarrhal conjunctivitis, or eye-strain due to faulty accommodation or convergence is often the cause of clonic spasm, and neurasthenia and hysteria must be considered. Clonic contractures, originating as a "habit spasm" may also have a purely nervous origin. See, in addition, p. 1112, Vol. II of this *Encyclopedia*.

Syringomyelia. Paralysis of the ocular muscles occurs in approximately 11 per cent. of the cases. It is, however, less frequent than in multiple sclerosis or tabes dorsalis. The paralysis generally sets in early and may be transient, but if it appears later it may become permanent. The abducens supply is more often involved than the other muscles, and usually the involvement is unilateral. The oculomotor nerve is as a rule only partially implicated, generally producing ptosis.

Nystagmus and nystagmoid movements occur in about 15 per cent. of the cases. The nystagmus usually comes on early in the course of the disease, although it may be a late manifestation. It may be horizontal, vertical, diagonal or rotary. The nystagmoid movements are more common than abducens paresis. In the nystagmus of syringomyelia there are, strange to say, no disturbances of vision, accommodation, or of the pupil reflexes. This argues against an acquired lesion. It is probable that the cause of the nystagmus in this disease is some congenital maldevelopment, and that the symptom does not appear until extensive involvement of the brain and spinal cord occurs.

The pupils are usualy not affected in syringomyelia, but miosis and

other differences may appear. The pupillary light reflex is generally present.

Paralysis of the sympathetic may be caused by a cavity in the lower portion of the cervical cord. Sympathetic ocular symptoms, when present, are generally unilateral. These are narrowing of the palpebral fissure, miosis, enophthalmus and disturbances of the ocular secretions. As a rule, we do not have all of these symptoms in sympathetic paralysis; for example, we may have only miosis with ptosis but without involvement of the secretory functions.

The ophthalmoscopic findings are usually negative. The discs may be pale throughout their whole extent, differing in this respect from the temporal pallor so often seen in multiple sclerosis. Vision is, as a rule, not interfered with, but if disturbances occur, both eyes are equally affected. Neither scotomata nor disturbances of light and color-sense have been recorded in this disease. A concentric restriction of the visual fields, especially for colors, and particularly for green, sometimes occurs, though these conditions may be due to an associated hysteria. See, also, **Syringomyelia.**

Tabes dorsalis. Locomotor ataxia. Pain in or about the eyeball is sometimes observed in tabes, especially early in the course of the disease. It may assume the character of a periodical neuralgia, or areas of anesthesia may be found in the course of the fifth nerve. Excessive lachrymation is regarded by some observers as an early symptom in tabes. Ataxic movements of the eyeballs are not infrequently observed, but a true nystagmus is very uncommon and when present may be congenital, or it may suggest the presence of some cerebral complication, such as multiple sclerosis. Twitchings of the eye, that resemble nystagmus when the eyes are turned as far as possible in one direction, are observed rather frequently.

In general terms, the symptoms of tabes consist of a triad made up of incoordination, loss of tendon reflexes, and the Argyll Robertson pupil phenomenon, in which the pupil no longer reacts to light, but in which the associated movements of the iris in accommodation and convergence are preserved. The actual lesion, producing this phenomenon (see p. 567, Vol. I of this *Encyclopedia*), whether it be in the nerve itself, in the ciliary ganglion, or in some possible connection between the nerve roots and the third nerve nucleus, has not been fully recognized. It has been suggested (Gunn) that the tabetic degeneration seems to be selective for the spinal cord: that the reflex collaterals are first affected, and that in more advanced cases the other fibres of the posterior columns also become degenerated. The fact that in the optic nerve we also recognize at least two different kinds of fibres

seems to be evidence of the verity of this hypothesis. The two varieties of optic fibrils are, first, those forming part of the visual path, and those conducting the stimulus which excites the reflex contraction of the pupil.

It may be added that there are several anatomic analogies between the optic nerve and the posterior spinal roots in the disposition of their sheaths and in their minute structure and, according to Gunn, it is not unreasonable to regard the ganglion of the root as performing a similar function as (though not strictly homologous with) the ganglion retinæ. It has been asserted, but by no means proven, that the chief incidence of the post-syphilitic toxins is on the ganglion cells of the posterior root ganglion; should this be so, it would be reasonable to assume that the ganglia retinæ are likewise first affected in the visual path, and that the fibre degeneration is secondary.

The myotonic pupillary movement is the name given to the phenomenon found by Saenger in tabes—that a pupil immovable to light, but reacting to convergence, remains contracted for several minutes after the act of convergence. According to Erb the pupil does not dilate in response to sensory stimuli when it is in a state of tabetic reflex immobility. Anisocoria is frequently found in tabes, but diagnostic importance can be ascribed to an inequality of the pupils only when the reaction is impaired at the same time.

Irregularity or deformity of the pupil is found quite frequently in tabes as in paresis and brain syphilis, and may be regarded as a precursor of the changes in the pupillary reflexes later to supervene. In size the pupil may be unusually small, normal or dilated, though mydriasis is met with much less frequently than miosis. It has been observed that during a gastric crisis pupils previously noted as normal may dilate, but that in such cases they return to their former size after the crisis has subsided.

Loss or impairment of the reaction of the pupil to accommodation and convergence may exist together with loss of light reflex, though such an association is infrequent. Ophthalmoplegia interna is very rare and is indicative of active syphilis rather than tabes. Paradoxical pupil is an exceedingly rare symptom, and hippus has been noted as occurring in but a few cases.

Ocular muscle palsies are extremely common in tabes, occurring, according to Uhthoff, in about twenty per cent. of the cases. They appear relatively early in the disease, involving variously the third, fourth and sixth nerves.

The partial loss of power appears suddenly and may disappear with or without treatment or, rarely, it may become permanent. The muscu-

lar involvement is seldom complete and is usually limited to one eye. Tabetic paresis of the oculomotor muscle is the most frequent, the abducens is affected less often and the trochlearis very rarely. The palsy is never one of associated muscles or movements. Occasionally a complete external ophthalmoplegia appears. As a rule the ocular palsies are associated with loss of light reaction. Blepharospasm may precede the development of ocular palsies and ptosis has been reported.

Optic atrophy occurs in from 10 to 20 per cent. of the cases of tabes and may be seen at any stage of the disease. The atrophy begins in the peripheral portion of nerve conduction apparatus, probably in the layer of ganglion cells and nerve fibres of the retina. Its onset is most frequent in the preataxic stage, and it may precede all other symptoms of the disease by several years. There is present in such cases a simple progressive atrophy of both nerves that frequently leads to complete blindness; in fact, simple optic atrophy, in the absence of other signs, is very suggestive of tabes. There is then a diminution of the acuity of vision with a progressive contraction of the visual fields. When the entire optic nerve is affected from the first a concentric contraction of the visual field takes place. The power of distinguishing red and green is lost first, even before there is any contraction of the form field; then the power to distinguish blue and yellow is lost, and finally the color-blindness is total. The more intense the colors and the higher the illumination, the longer can the colors be recognized. This fact, as Roemer points out, offers a point of differentiation between the loss of color-sense in atrophy and the congenital form of color-blindness. Occasionally the form field may show a high degree of concentric contraction while the color-sense is preserved for a longer time. In a small group of cases the first contraction of the visual fields may be in the form of sectors, but the contraction of the other segments of the field always follows in a short time.

Hemianopsia, incomplete in character, is a rare anomaly of the field and is apparently due to an asymmetrical degeneration. Dyschromatopsia may be present, the interlacing being mostly for red and green. See, also, **Tabes dorsalis**; as well as **Syphilis**.

Tic douloureux. Mimic spasm. Habit spasm. *Maladie des tics.* According to Church and Peterson (*Nervous and Mental Diseases*, p. 589), the French writers, following Giles de la Tourette, make a sharp distinction between a tic and other varieties of spasm. According to them a tic is a spasm identical with movements of volitional intent, and contain, therefore, a psychic element which may be subconscious. In facial tic they call attention to the nictitation. These

facial tics are more or less under the control of the patient, although repression may be followed by a "regular spasmodic debauch." While ordinarily the spasms are purely clonic they may, in long-standing cases, become tonic in character. Only the orbicularis oculi, frontalis and corrugator supercilii come under our consideration. These may be involved in a general facial spasm or they may be individually affected.

The etiologic factors in the causation of this disease and its ocular complications are, according to Winscheid (*Encycl. der Augenhl.*), divided into organic and functional diseases of the facial nerve. (a) The upper facial nerve fibres may be involved as to (1) its motor center in the ascending parietal convolutions by tumors, abscesses, or an area of softening; (2) its nucleus in the medulla oblongata by hemorrhage or by degeneration, as has been described in some cases of tabes; (3) in its trunk and its peripheral branches by tumors of the base of the skull, by arterio-sclerosis, aneurism, meningitis and diseases of the middle ear; (4) by diseases of neighboring nerves or organs, especially by lesions of the trigeminus set up by the teeth or eyes, or by compression at the base of the skull. Scrofulous diseases of the eyes may also set up spasms of the facial.

(b) Functional disturbances may be the chief factor, as part of a general nervous hyperirritability in chorea, epilepsy, migraine, tetany and especially hysteria. Irritation in a distant part of the body, or through pressure upon the nodal points, also belong here. Additional functional causes are irritation of the optic nerve by strong light, and intestinal worms, the spasm disappearing with the elimination of the parasites.—(W. R. P.)

Neurolymph. The cerebrospinal fluid.

Neurolysis. The liberation of a nerve from adhesions; the relief of tension upon a nerve obtained by stretching; exhaustion of nervous energy; destruction or dissolution of nerve tissue.

Neuroma, Ocular. Tumors mostly or entirely composed of nervous elements are occasionally found in the eye structures.

Although the majority of writers do not distinguish between neurofibroma and neuroma, it may here be said that the latter tumor is supposed to have a smaller percentage of connective tissue in its structure than a fibroneuroma.

Neuroma of the eyelids occurs, somewhat infrequently, usually in connection with similar tumors in other parts. The tumor consists of degenerated nerves and dense hyperplastic connective tissue, and forms tortuous nodosities which give the impression of cords rolling under

the fingers, and have been compared to a mass of earth-worms. It is congenital, and increases in size with the growth of the subject.

Plexiform neuroma of the eyelid is a rare growth which is really a fibroma developing from the sheaths of peripheral nerves, there being no new development of nerve fibres. The growth, which shows a peculiar predilection for the upper lid, is either congenital or appears in early infancy. The lid becomes grealy enlarged and of elephantiasis-like appearance, and ptosis results. The tumor is soft in general, with localized, cord-like spots which can be traced back into the orbit. In some of the recorded cases the face and eyeball have been involved. Usually the growth is not painful. The adjacent skin presents numerous spots of brownish-yellow color. Microscopically such growths are composed of nerve-bundles in masses of connective tissue. The treatment is excision. If incompletely removed the growth will return (Ball). See, also, p. 5019, Vol. VII of this *Encyclopedia.*

The *choroid* has been found occasionally affected with neurofibromatosis, in cases where this disease is extensive. Treacher Collins has examined two such cases, in both of which the eyes were buphthalmic. The choroid was considerably thickened and denser than normal, due to an abnormal overgrowth of its fibrous tissue elements. The fibrous tissue was arranged in layers, and was highly nucleated. Scattered throughout the thickened tissue were an abnormal number of deeply pigmented cells. The bloodvessels were few in number, and formed a much less conspicuous constituent than in normal eyes. In some cases there have been present in the hypertrophied tissue numerous sections of small oval bodies, with a nucleated cellular capsule and a core consisting of a convoluted fibre, similar to the bodies resembling nerve endings which have been described in a case of orbital plexiform neuroma. See, also, p. 2172, Vol. III of this *Encyclopedia.*

In two eyes which had become atrophic following iridocyclitis, Fuchs *(Trans. Amer. Ophthal. Soc.* XII, p. 786) found with the microscope small, true neuromata lying on the ciliary nerves in or beneath the choroid. The largest hung on the nerve like a plum on its stem. All were composed almost exclusively of medullated nerve fibers, with scarcely any connective tissue between them.

Simple neuroma is rarely found in the orbit, probably owing to the small size of the tumor and the absence of symptoms. In multiple neuromata the ophthalmic division of the fifth nerve is often involved. Bietti (*Archiv. f. Ophthal.*, XLIX, 1900) has described amputation neuromata of the ciliary nerves after opticociliary neurotomy. Tertsch (*Archiv f. Ophthal.*, LV, 1902) reported an isolated false neuroma or neuro-fibroma, probably of the lachrymal branch of the fifth. Plexi-

form neuroma (*cirsoid neuroma*, or *elephantiasia neuromatodes*) of the orbit is extremely rare. Extension from the upper lid to the tissues of the orbit is more common. They may occur in a number of members of a family, and may develop in the children of parents who are so afflicted. As Weeks says, the growth develops apparently from branches of the fifth, the supra-orbital branch being most frequently involved. It appears as a firm, elastic mass at the upper margin of the orbit, extends backward, may cause displacement of the globe and erosion of the wall of the orbit against which it impinges. The orbit may be entirely filled with the mass and the sensory nerves of the eyeball may participate in the change. Secondary hydrophthalmos has been reported in a number of cases. Sarcomatous degeneration occurs in a small percentage of cases. The neoplasm develops slowly; is almost devoid of pain, but is sensitive on pressure. The mass consists of coils of enlarged and varicose nerve trunks in a mass of scant connective tissue, and soft, yellowish, flat-like material. Sometimes the growths are encapsulated. Treatment is surgical; the removal must be complete. See also **Neurofibroma, Ocular.**

Neuromyélite optique aiguë. (F.) A term applied by Devic (1894) to the symptom-complex found in those rare cases in which an optic neuritis follows myelitis. See **Myelitis.**

Neuromyelitis optica. An affection—generally inflammatory—of the optic nerve due to myelitis.

Neuron. The cerebrospinal axis; a nerve-cell with its processes, collaterals, and terminations, regarded as a structural unit of the nervous system; in arthropods, the nervous part of the eye.

The ten layers of the retina are sometimes divided into three *neurons*. See, also, **Neurology of the eye.**

Neuroparalytic keratitis. NEUROPATHIC KERATITIS. See p. 6783, Vol. IX of this *Encyclopedia*.

Neuroploca. A nerve-ganglion.

Neuropodium. Any one of the delicate fibrils forming the termination of axis-cylinder processes.

Neuro-retinitis. PAPILLO-RETINITIS. CHOKED DISC. Inflammation of the retina as well as of the optic nerve. See p. 2074, Vol. III of this *Encyclopedia;* also under **Neurology of the eye.**

Neuroretinitis descendens. Neuroretinitis due to retro-bulbar inflammation of the optic nerve.

Neuroretinitis duplex. Neuroretinitis of both eyes.

Neurorrhaphy. The suturing of a cut nerve.

Neurorrheuma. A term used by White for nervous energy.

Neurosarcoma. A sarcoma with neuromatous elements.

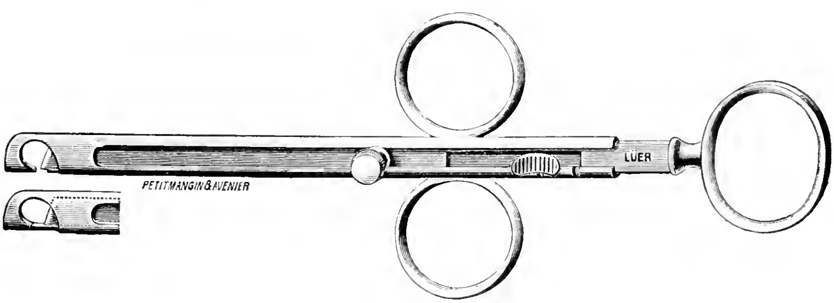
Neurosis. This term is employed to define a disease of the nervous system generally without lesion of the parts. It is often of hysterical character. Neuroses may be classified according to the organs or functions involved, thus: *visceral,* those of the respiratory, circulatory, or digestive organs, *localized paralysis; localized involuntary or reflex movements* such as spasms of the facial nerve and writer's cramp; *disorders of general sensibility,* including the various forms of neuralgia; *general neurosis,* as epilepsy, and hysteria; and *disorders of the mental faculties* as in melancholia.

Neurosis optica sympathetica. A term synonymous with sympathetic irritation, and characterized by functional disturbances in one eye, such as loss of accommodation, lachrymation, dimness of vision, hyperesthesia of the retina, etc. It is due to reflex transmission, from chronic irritation of the fibres of the trifacial nerve, from plastic iridocyclitis, or from cicatricial contraction of the other eye.

Neurosis, Traumatic. Hysteria and other nervous symptoms due to injury. It not uncommonly occurs as an ocular symptom. See **Hysteria**; and **Military surgery of the eye.**

Neurotabes. Multiple peripheral neuritis with symptoms like those of locomotor ataxia.

Neurotome, Joseph's. This instrument is described on p. 4462, Vol. VI of this *Encyclopedia* and depicted here. See the cut.



Joseph's Neurotome.

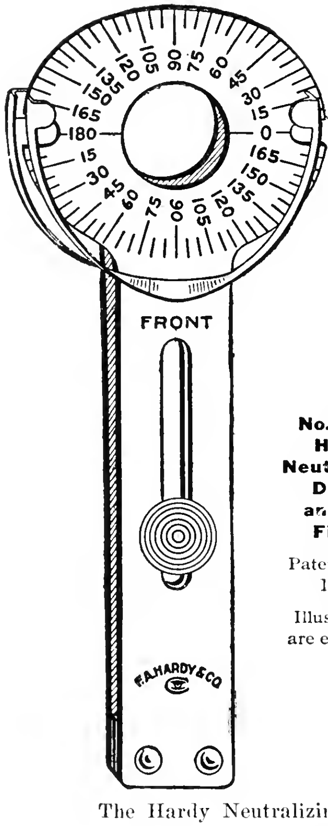
Neurotomy. The stretching of a nerve, chiefly to relieve pain.

Neurotomy, Opticociliary. See p. 4456, Vol. VI of this *Encyclopedia.*

Neurotomy, Pericorneal. For the relief of corneal lesions believed by him to be of neurophathic origin Verhoeff *(Trans. Amer. Ophth. Society,* Vol. XIV, Part i, p. 89, 1915) performs a partial peritomy, for which he proposes the name of *pericorneal neurotomy.* The conjunctiva is incised at the limbus with scissors, and then undermined with successive snips for a distance of 4 mm. or 5 mm. away from the limbus.

Care should be taken to cut all tissue down to the sclera. Finally, the flap is readjusted by a suture at each end of the incision, as in the van Lint operation for cataract.

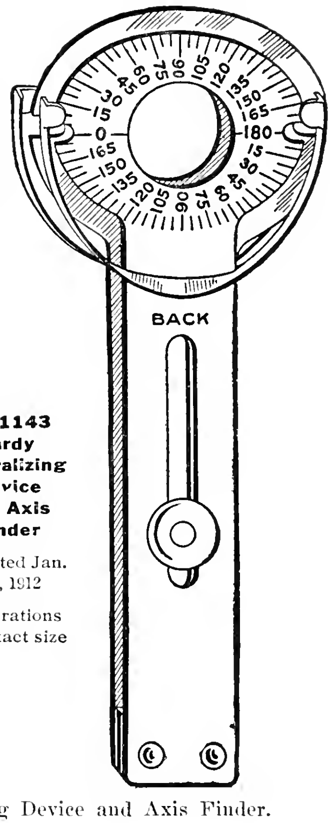
Neutralizing devices. Among the means of determining the refractive power and axes of lenses is the patented Hardy instrument shown in the text. It consists of two cells for holding trial lenses mounted on



No. 1143
Hardy
Neutralizing
Device
and Axis
Finder

Patented Jan. 16, 1912

Illustrations are exact size



The Hardy Neutralizing Device and Axis Finder.

separate protractors. The protractors have an opening in their centers, and a handle. The handles of the two, being riveted together at the bottom, form a clamp for holding the lens to be neutralized. The handles are slotted along their centers, and have a sliding rivet which is used to clamp them together. One of the protractors is the size and shape of a 1-eye lens; the other being the size and shape of a ooo-eye. Notches, in which may be placed the end pieces of frames or mountings. are cut in the ends of the protractors. These notches make it possible to place the lens to be neutralized, correctly, without removing it from its frame or mounting.

Neutralization of lenses. See p. 7264, Vol. X, of this *Encyclopedia*.

Neutral lines. The optic axis or axes of a crystal.

Nevi. See **Nævus.**

Nevolipoma. A nevus containing a large amount of fibro-fatty tissue.

Névrite. (F.) Inflammation of a nerve or group of nerves.

Névrite optique. (F.) Optic neuritis.

Névrosique. (F.) Neurotic.

Nevus. See **Nævus.**

Newborn, Eye of the. The eye of the newly-born child is distinguished from the adult eye chiefly by a shortening of about 7 mm. in the antero-posterior axis. The resulting hyperopia of some 30 D. is corrected only to a slight degree by the increased curvature of the cornea, as the corneal radius of the eye of a new-born child is about 7 mm. as compared with 7.8 mm. in the adult eye. In this way, however, only some three or four dioptres is neutralized. Inasmuch as an increase in the refractive indices of the media is very improbable, it is quite likely that the lens, whose form is more nearly spherical than in the adult eye, accomplishes the greater part of the refraction. The radii of the two surfaces of the lens in the new-born eye are only 3.5 mm. while in the adult eye the radius of the anterior surface is 10 mm., and of the posterior surface 6 mm.

As Heine (*Encyklopädie der Augenheilkunde*, p. 62) points out, a further peculiarity of the eye of the new-born is the greater curvature of the temporal half of the eyeball. It is also notable that the space between the fovea and the optic disc is practically as great in the infantile as in the adult eye, so that the fovea seems to be markedly temporal in position; hence, a sort of false exotropia is the result. According to Hippel, the thickness of the infantile cornea varies between 0.41 and 1.02 mm., as measured in prepared specimens. The anterior chamber is also more shallow than in the adult. The saggital diameter of the infant's lens is 4.3 to 5.1 mm.; equatorially, 5.2 to 7.2 mm.

In general, the ciliary muscle is but poorly developed, although in some instances one finds numerous circular muscle fibres.

Retinal folds, both at the ora serrata and at the macula, are recognized as artefacts. Schön denies the existence of an actual ora "serrata" in the eye of the new-born, though Hippel has observed it. A physiological indentation at the entrance of the optic nerve is ophthalmoscopically and anatomically demonstrable.

According to Hippel, the cones of the fovea in the eye of the new-born are strikingly undeveloped, being only 4-6 mikrons in length.

There is no pigment developed in the choroid, or, at most, a little at the posterior pole. In contrast to this, the pigmented epithelium of the retina is already deep black in color. The optic nerve shows little or no development. Hemorrhages are frequently observed after artificial delivery, both on the papilla and in the periphery. Hippel, for example, found a hemorrhage between the fovea and the pigmented epithelium. He believes this lesion to be the cause of certain forms of congenital amblyopia. It is quite common to find the remains of fetal vessels on both the lens and the papilla.

Rosenbauch *(Bericht der Akad. der Wissenschaft. in Krakau,* 1909), who examined bacteriologically the conjunctival cul-de-sac of 200 new-born children, finds that the sac is absolutely clear immediately after birth; the first microörganisms are to be found 24 hours after birth; after 24 hours the bacterial flora is constant; it is not to be differentiated from that of the adult; constant inhabitants of the sac are: *staphylocococcus albus non pyogenes non liquefaciens* and *bacillus xerosis;* other microbes are only sporadic; pathologic microörganisms are seldom found and then in small amounts; twenty-four hours after birth the author had never found a conjunctival sac free from micro-örganisms. He thinks that gonorrheal infection of the conjunctiva is hardly possible during birth, but usually occurs during the first two days of life.

Newnham, William. A well-known English surgeon, who paid considerable attention to diseases of the eye. Born in 1790, he studied at Guy's Hospital, London, and settled at Farnham, where he practised until his death from paralysis, Oct. 24, 1865. He was a Fellow of the Royal College of Surgeons of England, and a prolific writer.

Newnham's only ophthalmologic writing was "Case of Successful Operation for Melanosis of the Eyeball."—(T. H. S.)

Newton, Sir Isaac. One of the greatest natural philosophers of all time, author of the "*Principia,*" discoverer of "the law of gravitation," of the dispersion of light, of the composite nature of white light, of the unequal refrangibility of different colors, also propounder of the emission, or corpuscular, theory of light. He was born at Woolsthorpe, near Granthum, Lincolnshire, England, Jan. 5, (new style) 1643, the son of a small farmer, whose name was also Isaac. The father having died some months before the son was born, and the mother, three years later, having re-married, young Isaac was placed in the care of one of his grandmothers, who seems to have been regardless of his education, for he did not attend school until he was twelve years old. For a long time after that, he was, by his own confession, a careless and indolent scholar. He showed, however, a decided penchant for mechanics, and

constructed a number of sundials, windmills, cupboards, tables and little chests. At sixteen years of age, he returned to his mother, now once more a widow, and, for a time, engaged in farming. Showing but little taste or inclination, however, for this employment, he was sent by his mother, on the advice of her vicar, who was also her brother, to Trinity College, Cambridge. Here the giant that was in young Isaac then awoke, and all his studies seemed to him thereafter to be too easy. His Bachelor's degree was taken in 1665, and his Master's two years later. Two years later still he was chosen by Barrow, a professor at Cambridge, to edit the latter's "*Geometrical and Optical Lectures.*" Newton was elected Lucasian professor of mathematics at Cambridge in 1669. From 1669 till 1671 he lectured on optics, in addition to mathematics, and, in these optical lectures, announced the most of his optical discoveries.

Newton published in 1675 his "*Discourse on Light and Colours,*" and in 1704 the first edition of his "*Opticks: or, A Treatise of The Reflections, Refractions, Inflections and Colours of Light.*" Other English editions of the book appeared at London, in 1716, 1721 and 1730; Latin editions, at London, in 1719, 1721, and 1728; French editions, at Paris, in 1720, 1726, 1737, and at Lausanne, 1740; an Italian edition, at Padua, 1773.

Newton's "*Opticks*" is divided into three books, the first treating "Of the reflexion,* refraction and dispersion of light"; the second, "of the reflexions, refractions and colours of thin transparent bodies"; the third, of "the inflexions (diffraction) of the rays of light, and the colours made thereby." † Then follows a series of questions, or queries, concerning certain incomplete experiments and unsolved problems, Newton remarking rather definitively, by way of preface, "I cannot now think of taking these things into farther consideration."

For Newton's relations to his predecessors and successors in the optical field, we refer the reader to **Ophthalmology, History of,** and of Newton's other great achievements, as well as of certain political matters, such as his seat in Parliament, his appointment as master of the mint, etc., we have no warrant to speak in this *Encyclopedia.* We may say, however, that Newton was Master of the Mint at the time of his death. For a number of years he was troubled with incontinence of urine, probably due to stone, and in January, 1725, he was seized with a violent cough together with pulmonary inflammation. A little

* Newton spelled the word both with *x* and with *ct,* often indeed employing both forms in the same paragraph or sentence.

† These book-heads are given from my own copy of the "*Opticks,*" second edition. I am under the impression that, in the first edition, the heads are expressed somewhat differently.

later still, he suffered an acute attack of gout, and died on Monday, Mar. 20, 1727, aged 84. His body lay in state in the Jerusalem chamber, and was buried in Westminster Abbey.—(T. H. S.)

Newtonian aberration. Inequality in the degree of refraction of the rays of the different colors.

Newtonian telescope. A front view reflector, in which the rays are deflected to the eyepiece by a flat mirror placed at an angle of 45° to the optical axis.

Newtonian theory of light. See **Light.**

Newtonic rays. The visible rays of the spectrum.

Newton's color disc. A disc painted with colored sectors, used to demonstrate the composition of white light.

Newton's rings. In his investigations of the colors produced by thin plates of any material, solid, fluid, or gaseous, Sir Isaac Newton hit upon the following mode of exhibiting the colors produced by reflection from a film of air. He took two lenses, one convexo-plane, the other equi-convex, and laid the first with its plane surface downwards on the top of the second, thus producing a thin film of air between the lenses. On slowly pressing the upper lens against the under one, a number of concentric colored rings, having the point of contact of the lenses for their center, appeared, and increased in size when the pressure was increased.—*(Standard Encyclopedia.)*

New York interval. In alphabets and print for the blind (q. v.), this phrase refers to the variable base (q. v.) with a one-point space between letters which have been used for many years in New York point. Hence, when Braille is written with the same spacing, it is commonly known as Braille with New York point intervals.

New York point. See **Alphabets for the blind,** p. 266, Vol. I of this *Encyclopedia.*

Niaouli oil. See **Gomenol,** p. 5604, Vol. VII of this *Encyclopedia.*

Nicaise of Malines. A famous blind priest. See **Werde, Nicaise de.**

Nichet, J. N. P. A French physician, obstetrician, and ophthalmologist. Born in 1803 at Frontignan, Hérault, he graduated at Montpellier in 1829. He became in 1832 physician-in-chief at the Lyons Charité, and professor of obstetrics at the Ecole de Médecine. He wrote a number of articles of a general character, and one on iritis. He died of tuberculosis of the lungs, Oct. 27, 1847.—(T. H. S.)

Nicolle and Blaizot's vaccine. This is an anti-gonococcal remedy consisting of 1 part of gonococci grown on glucose-gelose (rabbit's serum), emulsified and well washed in a 7 per 1,000 solution of fluoride of sodium, and 9 parts of syncoccus similarly treated. The syncoccus is a coccus which is usually associated with the gonococcus in urethral

gonorrhea, but grows on media without serum, with an orange color, and is Gram-positive. When inoculated in human beings, it provokes no reaction, and has the same curative action as gonococcic vaccines. The fluoride of sodium is used because it does not coagulate albumin, causes only slight alterations in the microbes, and prevents autolysis. One cubic centimetre of the serum contains 500 million microbes. The injections were given intramuscularly in children, and intravenously in adults. As a rule, they were repeated every second day, the first consisting of ½ c.cm., and the subsequent ones of 1 c.cm. To avoid the caustic action of the fluoride, the serum was diluted with from 1.5 to 2 c.cm. of physiological serum.

Offret (*Annal. d'Oculist.*, Feb., 1914; review in the *Ophthalmoscope*, p. 317, May, 1915), who has treated 32 cases of gonococcal ophthalmia, finds that intravenous injections never cause any local reaction, but the intramuscular ones were sometimes followed by redness, and exceptionally gave rise to slight induration. In adults a slight general reaction, consisting of a rigor, with elevation of temperature to from 38° C. to 39° C., and occasional nausea, was the rule on the evening following the injection, but these symptoms always passed off before the following morning.

Irrigations were always given in addition to the vaccines, and the great majority of the cases were also treated with silver nitrate and argyrol.

The cases treated were classified as follows.—(1). Ophthalmia neonatorum, fifteen cases, nine without and six with corneal ulceration. (2). Conjunctivitis in children and adults, thirteen cases, seven without and six with corneal ulceration. (3). Metastatic conjunctivitis, three cases. (4). Iritis, one case. In two of the cases of ophthalmia neonatorum, corneal ulcers developed while the patients were under treatment with the vaccine, in spite of diminution of the discharge and the swelling of the eyelids. In one of these no silver preparation was used.

The conclusions drawn from the investigation are that the vaccine of Nicolle and Blaizot almost always diminishes the inflammatory symptoms in ophthalmic gonococcal inflammation, and frequently reduces the secretion, rendering it clear and mucous in place of thick and purulent. As a rule, however, the secretion does not disappear as quickly as the inflammatory symptoms, and a slight amount containing gonococci may persist for a long time after all visible lesions of the lids and conjunctiva have disappeared. These quiescent forms of conjunctivitis retain their serious nature, as they can cause relapses with corneal complications, and the treatment of gonorrheal ophthalmia

should therefore aim at getting rid of every trace of secretion. The vaccine appears to give particularly good results in metastatic conjunctivitis, but has no favorable action on corneal ulcers complicating conjunctivitis.

Practically, the vaccine is a valuable therapeutic agent, but for the present should be used in conjunction with the classical treatment by irrigation and preparations of silver.

Nicolle's stain. This is a (bacterial) thionin stain recommended by Morax. The nuclei of the cells are colored blue; the bacteria themselves reddish. Saturated sol. of thionin in 50 per cent. alcohol, 10 parts; aqueous solution of carbolic acid, 1 part. Keep in solution one-half to one minute; then wash in water.

Nicol, or Nicol's prism. Two prisms composed of *calcite* (q. v.), a crystal whose natural end-faces are parallel and inclined at an angle of about 71° to the blunt edges of the longer sides. The crystal is cut so as to form new end-faces inclined at 68° to the edges, and of such length as to be divided into two parts by a diagonal cut through it which is perpendicular to the parallel end-faces. The two right-angled prisms of calcite thus formed, are again joined together in their original position by a film of Canada balsam, after the separated faces have been ground flat and polished. The ordinary ray being totally reflected by the film of balsam, allows the extraordinary ray to be transmitted through the prism and to emerge in a direction parallel to the incident ray, so that a ray of pure polarized light of considerable intensity is obtained. When two Nicol's prisms are placed end-to-end with their principal sections or end-faces parallel, the light is transmitted through both Nicols, and as one of them is rotated, the transmitted light gradually grows more feeble, until the principal sections are crossed at right angles to each other, when no light is transmitted. With such *crossed* Nicols, the extraordinary ray from the first Nicol forms in the second an ordinary ray that is totally reflected by the balsam film. The Nicol may be used either as an analyzer or polarizer. See also **Polarization.**—(C. F. P.)

Nicomors. Tablets containing magnesium dioxid and tannic acid, for use by smokers to counteract the effect of nicotin.

Nicotiana tabacum. VIRGINIAN TOBACCO-PLANT. A species indigenous to tropical America, now widely cultivated in both hemispheres. It has a simple unbranched stem, sometimes 6 feet high, bearing at the top a panicle of pink flowers. The dried leaves, the *tabacum* of the U. S. Ph., have a peculiar penetrating odor wanting in the fresh plant. They contain nicotine, nicotianine, a very small percentage of essential oil, malic, citric, acetic, oxalic, and pectic acids, and a small

proportion of sugar, cellulose, albuminoids, and of fats and other bodies extractable by ether. Tobacco-smoke is very complex in composition, but, if nicotine (which does not occur, according to Vohl and Eulenberg) is excepted, the only constituents found in appreciable quantities are numerous basic substances of the picolinic series. A dark-brown, acrid, highly poisonous empyreumatic oil is obtained from tobacco by distillation. Tobacco used in moderation causes in those accustomed to its use a gentle exhilaration or a state of quietude and repose. Its excessive use produces dyspepsia, general anemia, amblyopia from neuritis, and cardiac distress. Its active principle, nicotine, is a powerful sedative poison which has a depressant action on the motor-nerve trunks. See **Toxic amblyopia**; as well as the heading **Tobacco.**

Nicotianin. A volatilizable and fragrant crystalline principle from tobacco.

Nicotin. $C_{10}H_{14}N_2$. This volatile liquid alkaloid is the active principle of the tobacco-plant, in all parts of which it occurs in combination with malic and citric acids. When pure and freshly prepared it is a colorless, intensely poisonous liquid, which evolves a very irritating odor of tobacco, but on exposure to the air it rapidly oxidizes and becomes brown in color. It is moderately soluble in water, and dissolves readily in alcohol and ether. The quantity of nicotine in tobacco varies from 2 to 8 per cent.; the coarser kinds contain the larger quantity, while the best Havana cigars seldom have more than 2 per cent., and often less. See **Toxic amblyopia.**

Nicotinism. NICOTISM. Tobacco poisoning.

Nictation. NICTITATION. Winking; a more or less rapid and repeated opening and closing of the eyelids.

Nictitating membrane. The so-called third eyelid of various animals, especially of birds and reptiles. See **Comparative ophthalmology**; p. 2627, Vol. IV of this *Encyclopedia.*

Nictitation. WINKING. PALPEBRAL REFLEX. The occasional closure of the lids through the action (mainly) of the orbicularis palpebrarum muscle is a normal and necessary act. Its frequency varies somewhat in health from 3 to 6 times a minute. The rapidity of the movement is increased in proportion as there is fatigue of the accommodation or of convergence, or of the retina itself, and when there is irritation of the cornea and conjunctiva. Neurasthenic subjects wink oftener than normal persons, while the eyes of those afflicted with paralysis agitans and exophthalmic goitre are characterized by long intervals of fixed staring.

Abnormal conditions of the system in general modify nictitation.

This is seen, for example, in the Stellwag sign of exophthalmic goitre. See p. 4807, Vol. VI, of this *Encyclopedia.*

Niederdrücken des Staars. (G.) Depression of cataract.

Niederschlag. (G.) Precipitate.

Niederziehender Augenmuskel. (G.) The inferior rectus muscle.

Niere. (G.) Kidney.

Niewenglowski's ray. Luminous rays given out by substances which have been exposed to the sun.

Night-blindness. NYCTALOPIA. This section should be read in conjunction with **Hemeralopia,** p. 5760, Vol. VIII of this *Encyclopedia,* with which it is often confounded; as well as with **Nyctalopia,** the major heading.

Night-eyed. Sharp-eyed; nyctalopic.

Night-glass. A binocular telescope of high light collecting and small magnifying power, principally used in the navy.

Night telescopes four times as effective as those that have long been in use by marine officers have been perfected comparatively recently and are now in practical service. It hardly seems possible that a telescope could be of much use in bringing nearer or making more distinct a distant ship or building at night, but the modern night glasses do give an astonishing amount of assistance to the eye.

Under the old theory, any attempt to magnify a distant object very much—over three or four diameters, for instance—would be disastrous, because only so much light could come to the eye from the distant object; and spreading this scanty light over a wide space by much magnifying would simply result in blurring the object, making indistinct objects even less distinct.

The new glasses, according to the *Saturday Evening Post,* Feb. 13, 1915, avoid this trouble by using the principle of adapting the pupil of the eye to the amount of light. Everyone is familiar with the changing pupil of a cat's eye—a narrow slit by day and a big disk by night—opening up at night to admit all the light obtainable. The old night glasses focused the light to a point, and the light entered the eye of the observer practically as a point.

The new glasses focus the light into a pencil one-fifth of an inch in diameter, because it has been found that the pupil of the human eye will admit a pencil of dim light of that width at night. Consequently the eye can take better advantage of such light as there is, and the modern night telescopes can magnify to eight diameters safely. Tests have shown them to be four times as effective as the old night glasses.

Nightshade, Deadly. *Atropa belladonna.* This is an erect, perennial, European herb, from 3 to 5 feet high, bearing dull-green, ovate, entire leaves having a peculiar heavy odor and a fatty feel, and solitary, axillary, dull-purplish, bell-shaped flowers on drooping stalks. The fruit is a dark, shining, many-seeded berry, resembling a cherry in shape and attached in the base of the permanent calyx. The branches, the inferior surface of the leaves, and the peduncles are pubescent. The root is carrot-shaped, branching, dirty-yellow externally, white within. The root and leaves contain atropia and other poisonous alkaloids. See, also, p. 924, Vol. II of this *Encyclopedia.*

Night-sight. Day-blindness; hemerolopia.

Nigricans, Acanthosis. See **Acanthosis nigricans,** p. 48, Vol. I of this *Encyclopedia.*

Nigricans, Keratosis. See p. 6836, Vol. IX of this *Encyclopedia.*

Nigricans, Seborrhea. See p. 6837, Vol. IX of this *Encyclopedia.*

Nigridine. This proprietary substitute for potassium iodide is said by the owners to be useful in exophthalmic goitre and, it is claimed, is a purely organic compound obtained by synthetic process, and represents the combined, specially prepared concentrations of the thyroid gland of the sheep, and the thymus gland of the calf, the process eliminating the heart-depressing principle from both glands, each grain of nigridine being equivalent in therapeutic actions to approximately 5 grs. of potassium iodide without producing iodism, irritating action on the mucous surfaces, or any digestive derangement.

Nigrification. The act of making black.

Nigrities. Dark pigmentation.

Nigritude. Blackness.

Nigrosin. Anilin-black, $C_{36}H_{27}N_3$; a microscopic stain.

Nigrum oculi. (L.) The pupil.

Nilei collyrium. An ancient collyrium made of Indian nard, opium, gum, saffron, fresh rose-leaves, and rain-water or light wine.

Nimmo, William. A Glasgow surgeon, who devoted considerable attention to diseases of the eye, and who was widely known as an ophthalmic operator. The date of his birth is not known. He became, however, in 1831, Fellow of the Medico-Chirurgical Faculty of Glasgow; in 1834 assistant physician at the Glasgow Eye Infirmary (as well as professor of surgery at the private medical school in College Street) and in 1835 M. D. at the University. He seems to have written nothing on the eye. He died at Demerara, West Indies, in 1841.—(T. H. S.)

Ninhydrin. A reagent for proteins and amino-acids used, *inter alia,* in some oculotoxic investigations; also for diagnosing pregnancy.

Niphablepsia. (Obs.) Snow blindness.

Niphotyphlosis. Niphotyphlotes. Blindness caused by "glaring" from the sunlight on snow.

Nirvanin. This drug is, chemically, a complicated oxybenzoylmethyl ester, occurring as colorless crystals readily soluble in water. It is said to be less poisonous than orthoform, for which it is offered as a substitute.

As a local anesthetic it has not met with favor in ophthalmic therapy, although it is much less poisonous than cocain, its solutions can be boiled with impunity and it is decidedly antiseptic. On the other hand it is but feebly anesthetic and in from 1 to 4 per cent. solution is decidedly irritating to the ocular tissues.

Nistagmo. (It.) Nystagmus.

Nitency. (Obs.) Brightness; lustre.

Nitid. (Obs.) Lustrous; shining.

Niton. A condensable gas given off by radium and regarded as an element, having an atomic weight of 222.4. It forms the radio-active element of radium and is used like the latter.

Nitramin. One of the recent antiluetic remedies.

Nitrate of silver. See **Silver nitrate.**

Nitre lunaire. (F.) Silver nitrate.

Nitre of Venus. Copper nitrate.

Nitric acid. See **Acid, Nitric,** p. 71, Vol. I of this *Encyclopedia.*

Nitrite of amyl. See **Amyl nitrite,** p. 332, Vol. I of this *Encyclopedia.*

Nitrobenzene. A synonym of nitrobenzol.

Nitrobenzol. Dinitrobenzol nitrobenzene. A poisonous benzol derivative, $C_6H_5NO_2$. It is a sweet, oily liquid, used in perfuming soap and as a flavoring agent. It is an active poison, sometimes producing an amblyopia. Called also *oil of mirbane* and *artificial oil of bitter almond.* See p. 3973, Vol. V of this *Encyclopedia.*

Nitrogen monoxide. Nitrous oxide. Laughing gas. A colorless gas, N_2O, of agreeable odor and sweetish taste. By the application of cold or of suitable pressure it may be reduced to a liquid boiling at 87.9° C., and by still further reduction of temperature to a crystalline solid. When inhaled together with oxygen it produces an exhilarant and intoxicating effect; when inhaled by itself it produces complete anesthesia, lasting, however, for a brief period only, and not always associated with loss of consciousness. See **Anesthesia**; p. 432, Vol. I of this *Encyclopedia.*

Apart from its use in ophthalmic surgery there are certain toxic effects to be considered that (rarely) affect the eye. Even in this instance the ocular symptoms are generally due to the mechanical effects of the struggling and vomiting on the bloodvessels of the eye. As an

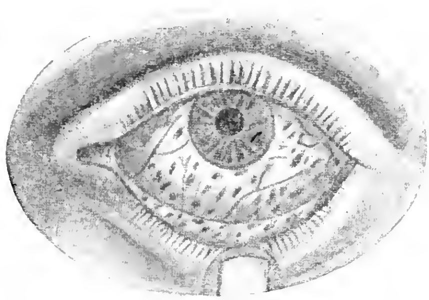
example is H. McI. Morton's case (*Ophthalmic Record*, p. 79, Vol. VIII) as shown in the accompanying cut.

Nitroglycerin. Spirit of glyceryl trinitrate. Solution of trinitrin. This well-known agent is really a one per cent. solution, by weight, of nitroglycerin in alcohol. It is a clear, colorless liquid and is used as an arterial stimulant in various cardiac diseases, in dosage of from one to two minims. It is infrequently employed in ophthalmic therapeutics, but is occasionally given in some forms of optic atrophy.

Nitronaphthalin. A yellow, semi-crystalline substance directly obtainable from naphthalene by nitration. Its fumes are very irritating and have caused vesication and opacity of the cornea in those exposed to it.

Nitrosin. A preparation for treating cancer, prepared by Ehrlich.

Nitrostyrol. A substance crystallizing from alcohol in yellow rhombic prisms having a strong cinnamon-like smell and taste and melting



H. McI. Morton's Case of Hemorrhage into the Conjunctiva Following Nitrous Oxide Inhalation.

at 58 C. Nitrostyrol blisters the skin and its vapor attacks the eyes and nose violently.

Nitrous oxide. See **Nitrogen monoxide**; also **Anesthesia**; p. 432, Vol. I of this *Encyclopedia*.

Nizin. See **Zinc sulphanilate.**

Noctidial. Comprising a day and a night.

Noctiluca. This phosphorescent, marine infusorian, common to most seas, is one of the chief causes of the "phosphorescence" of the waves. It is spherical, 1/50 in. in diameter and moves by means of a long, stout lash or flagellum, and an additional, smaller one lying in the "mouth" region.

Noctilucent. Noctilucid. Noctilucous. Shining by night or in the dark.

Noctilucin. The light emitting substance in phosphorescent animals.

Noctograph. A writing-frame for the blind; as the name implies, an instrument for writing in the dark.

Nocturne. A painting or photograph presenting the characteristic effects of night-light.

Nodal. Pertaining to nodes or a node.

Nodal planes. See **Principal planes.**

Nodal points. Two points so situated on the optical axis of a dioptric system that every ray directed towards one of them is represented after refraction by a ray emanating from the other. See **Cardinal points of a lens.**

Node. An absolutely, or relatively, stationary point or line in any vibrant substance; a swelling or protuberance.

Nodine, Francois O. An American ophthalmologist and oto-laryngologist. Born at Meadville, Ohio, in 1865, he received his medical degree at Wooster University in 1886. After a year or more of ophthalmologic study in New York City, he settled as ophthalmologist in Cleveland, Ohio, and for three years practised with Dr. D. B. Smith. For a short time he was Professor of Diseases of the Eye and Ear in the Medical Department of Wooster University. He never married. He died on the steamer *La Bourgoyne*, on the way from Hâvre to New York. Nov. 24, 1890.—(T. H. S.)

Nodular choroiditis. See p. 2156, Vol. III of this *Encyclopedia.*

Nodular conjunctivitis. See p. 3123, Vol. IV of this *Encyclopedia.*

Nodular cyclitis. NODULAR IRIDOCYCLITIS. This term has been applied to that condition—generally a part of sympathetic ophthalmia—in which nodules of lymphocytes are found in the iris and ciliary body. Parsons has given to this condition (which he says is not uncommon in chronic inflammation) the name *nodular iridocyclitis.* The nodular aggregations are commoner in the iris and choroid than in the ciliary body; they may contain numerous giant-cells, as well as epithelioid cells, so that the resemblance to tubercle is very striking; this occurs more frequently in the choroid than in the ciliary body or iris. See, also, **Cyclitis in general,** p. 3612, Vol. V of this *Encyclopedia.*

Nodular iritis. See **Iritis nodosa,** p. 6667, Vol. IX of this *Encyclopedia.*

Nodular keratitis. See **Cornea, Nodular opacity of the,** p. 3410, Vol. V of this *Encyclopedia.*

Nodular opacity of the cornea. R. R. James (*Ophthalmic Review*, p. 24, Jan., 1916) finds that the paper of Rodriguez (*Revista de clin. y terap. ocular*, No. 1, 1915) does not deal with the familial disease described on p. 3410, Vol. V of this *Encyclopedia*, but rather with an odd type of corneal degeneration occurring in cases of old trachoma, which was first investigated by Groenow in 1898 and subsequently by Fuchs.

The author's first case was that of a woman with old, largely untreated trachoma, whose corneæ presented numerous spots of opacity superficially situated, which covered over the whole pupillary area and left only a tiny rim of clear cornea in the periphery. Vision was very much reduced thereby. His second case occurred in a man, also an old trachomatous patient, and the cornea presented a very similar appearance, but the vision was not so much reduced as in the first case.

In each case Rodriguez found electrotherapy of great benefit. He performs the operation under cocain anesthesia, the patient's hand being connected with the positive pole, while the negative pole is attached to a lachrymal sound, which is moved about slowly over the opacities, while the strength of the current is very gradually increased to 1 milliampere, and then as gradually diminished. A fine scum is formed at the points of contact between the probe and the cornea. The length of time during which the current is running is not stated.

Rodriguez has noted an obvious clearing of the opacities after each application of the treatment, and he is very strongly opposed to using any stronger current than 1 milliampere, as has been advised by Sulzer. A fairly sharp inflammatory reaction usually follows each application, which, however, begins to subside after 24 hours; it is not as a rule a very painful procedure, and photophobia quickly diminishes. The applications were repeated every two or three weeks, while in the period of repose dionin and mercurial ointment was used. Compare, also, **Keratitis, Superficial punctate,** p. 6814, Vol. IX of this *Encyclopedia.*

Noduli corneæ. See **Keratitis, Superficial punctate,** p. 6814, Vol. IX of this *Encyclopedia.* The major caption is sometimes (and may easily be) confused with the term *nodular keratitis.*

Noël, Leon Gislain. A celebrated Lyons surgeon, who devoted most of his time and energy to ophthalmology. Born in 1845, he studied at Lyons, lectured there on "operative medicine," and in 1874 succeeded Hairion as chief of the Eye Division of the Lyonese Civil Hospital. He was a skillful operator. He also discovered the venous pulse in those awakening from chloroform narcosis. This brilliant young man passed from life May 11, 1877, aged only 32.

Noël's most important ophthalmologic writings are: 1. Sur la Myopie. (*Bullet. de l'Acad. Roy. de Méd. Belgique*, 1875.) 2. Histoire Thérapeutique de l'Atropine dans l'Ophthalmologie. (*Jour. des Sc. Méd. de Louvain*, 1876.) 3. A chapter on the eye in Haan's "*Abrégé de Pathologie Chirurgicale.*"—(T. H. S.)

Noematachometer. An apparatus invented by Donders for estimating the time taken in recording a simple sensation.

No-glare glass. See **Eyes of soldiers, sailors, etc., Examination of the.**

Noguchi's (luetin) test. See p. 7543, Vol. X of this *Encyclopedia.*

Noli-me-tangere. Rodent ulcer; malignant ulcer.

Noma. See **Eyelids, Gangrene of the.**

Non-actinic rays. Rays that are photo-chemically inactive.

Non-coincidence. A lens-defect to which it is due that the optical and chemical foci fail to coincide.

Non-conductor. Any substance that does not readily transmit electricity, light, or heat.

Non-magnetic foreign bodies. See **Localization,** p. 7503, Vol. X of this *Encyclopedia.*

Nonophthalmos. Absence of the eyeball. See **Anophthalmia,** p. 501, Vol. I of this *Encyclopedia.*

Non-radiable. Impervious to rays, such as X-rays, cathode rays, etc.

Noon-mark. A point which is indicated by the projection of the sun's rays at noon.

Noratropin. A mydriatic alkaloid from scopola, datura, and various other solanaceous plants.

Nor-hyoscyamin. A mydriatic alkaloid from certain solanaceous plants.

Norm. A fixed or ideal standard.

Normalauge (von Donders). The eye that exhibits a standard dioptric system.

Normal dispersion. Chromatic dispersion in which the colors of the spectrum produced are disposed in the usual order, i. e., in the order orange, yellow, green, blue, indigo, and violet.

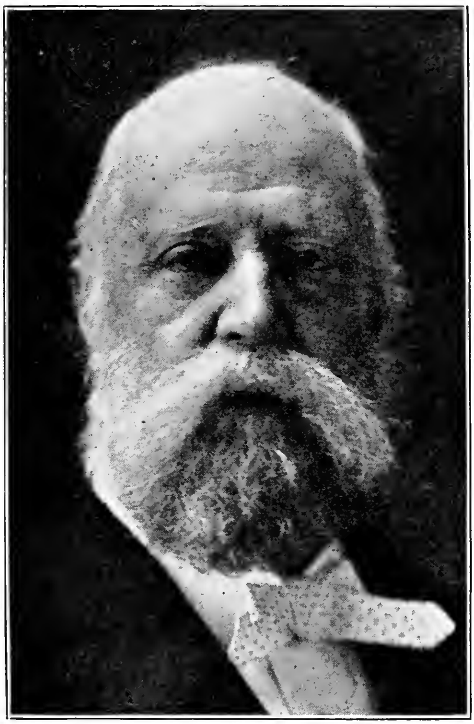
Norma occipitalis. The profile of the skull from behind, the skull being on a level with the eye; a line tangent to the occipital bone and parallel to the facial line.

Norremberg doubler. A form of polariscope in which the polarized ray twice traverses the object under examination.

Norris, William Fisher. A famous American ophthalmologist, one of the authors of Norris and Oliver's "*Text-Book of Ophthalmology*" and one of the editors of Norris and Oliver's "*System of Diseases of the Eye.*" Born in Philadelphia, Jan. 6, 1839, the son of Dr. George W. Norris and Mary P. (Fisher) Norris, he received the degree of Bachelor of Arts from the University of Pennsylvania in 1857 and the degree of M. D. from the same institution in 1861. Serving as resident physician in the Pennsylvania Hospital for eighteen months, he entered the Federal Army as assistant surgeon, and was placed in charge of the Douglas Hospital at Washington. This position he resigned in 1865, having received the brevet rank of captain. It is said that, at one time, Dr. Norris "operated and dressed wounds continuously for thirty-six hours, without food or rest."

At the close of the war, i. e., in the autumn of 1865, Dr. Norris proceeded to Europe, where he studied ophthalmology under Arlt, Jaeger and Mauthner. Under Stricker he made extensive investigations into the pathologic histology of the cornea, the results of which appeared in Stricker and Norris's "*Versuche über Hornhautentzündung.*"

Returning, in 1870, to Philadelphia, he was appointed lecturer in



William Fisher Norris.

ophthalmology and otology at the University of Pennsylvania. While in this position, he established, in conjunction with Dr. Strawbridge, "the first of the special clinics in that institution." A little later, deciding to limit both his practice and his teaching to ophthalmology, he assigned to Dr. Bertelot the part of his teaching which dealt with diseases of the ear. In 1873, when the University was removed to West Philadelphia, Dr. Norris was made Clinical Professor of Ophthalmology. In 1876 he received the full professorship, and retained it until his death, many years afterward. He passed away Nov. 18,

1901, the immediate cause of death being pneumonia, though the remoter causes were diabetes, rheumatism, and rheumatic gout.

Dr. Norris was a man of impressive presence and of high moral character. Concerning his physical appearance, Dr. Risley has written as follows: "He was [when Dr. Risley first met him] thirty-three years of age, possessed of a massive frame, well rounded, not corpulent, a large, dome-like head, with the blond hair of a Norseman, trimmed in the conventional form, a full beard, not long, light in color, fine in texture, a complexion ruddy with the tints of perfect, vigorous health, and a calm, benignant manner, striking in one of his age, which found expression largely through his clear, blue, unhesitating eyes." Concerning his personal character, the following is from his great colleague (now, also, alas! departed from us) Dr. Charles A. Oliver: "Gentle of nature and kindness itself in disposition in his home life, his own true self could only be appreciated by those who were drawn the closest to him. Firmness, will-power, and great mental restraint marked him in his public life. Courteous and dignified in all of his actions and the fortunate possessor of rare good judgment and common sense, made him constantly sought for by those who needed fair and impartial advice upon questions of the greatest importance and delicacy of handling. Personal ambition and increased power never exercised any control over his actions. His life was a subjugation of the man for the right. He worked indefatigably for one purpose—the good of ophthalmology and his alma mater." To this I may add that Dr. Norris bought the original drawings for Jaeger's "*Atlas of the Diseases of the Ocular Fundus*" for 4500 florins cash—a fact suggestive of the love which he bore to his profession.

Norris's most important ophthalmologic writings, in addition to those above referred to, are as follows:

1. Albuminuric Retinitis. (In Dr. Tyson's *Monograph on Bright's Disease.*)
2. Diseases of the Crystalline Lens. (In the "*System.*")
3. Investigations of Double Staining in Microscopical Work. (In collaboration with Shakespeare.)
4. A Description of the Anatomy of the Human Retina. (In collaboration with Wallace.)
5. Foreign Bodies in the Orbit.
6. Brain Tumor with Interesting Eye Symptoms.—(T. H. S.)

North, Elisha. A distinguished American physician, known chiefly as an early vaccinator and writer on epidemic cerebro-spinal meningitis, but of interest to ophthalmologists because of his having founded the first eye dispensary in the United States. Born in Goshen, Conn., Jan.

8, 1771, the son of Dr. Joseph North, he received his medical degree at the University of Pennsylvania. Practising for a time at Goshen, he removed in 1812 to New London. Five years later he established in that city the first eye infirmary in the United States. He married, Dec. 22, 1797, Hannah, the daughter of Frederick Beach, of Goshen, by whom he had eight children. He died Dec. 29, 1843.—(T. H. S.)

Northern Homer, The. A blind Scottish minstrel of the 14th century. See **Henry the Minstrel.**

Norton, George S. A prominent homeopathic oculist of New York City. Son of Salmon K. and Jane S. Norton, he was born at New Marlboro, Mass., Dec. 8, 1851. His liberal training was received at the Sedgwick Institute, Great Barrington, Mass., and at Dartmouth College; his medical degree at the New York Homeopathic Medical College in 1872. He at once became House Surgeon to the New York Ophthalmic Hospital, and, in 1875, surgeon to the same institution. In 1883 he was promoted to the Board of Senior Surgeons, and four years later became a member of the Board of Directors. For many years he filled the chair of ophthalmology in the College of the New York Ophthalmic Hospital, and in 1886 was called to the corresponding chair in the New York Homeopatic College. He was for a time surgeon to the Laura Franklin Free Hospital for Children and to the Ward's Island Homeopathic Hospital. He was once President of the American Homeopathic Ophthalmologic and Otologic Society. He was the founder and for many years the editor of the "*Journal of Ophthalmology, Otology and Laryngology.*" He wrote a large and esteemed text-book, "*Ophthalmic Therapeutics.*"

He married, in 1875, Miss Kate West Graham, of New York City.

A man of warm heart and great generosity, he had numerous loyal friends. His integrity was never questioned. He was a man of delicate build and constitution, of a fine, sensitive, girlish complexion, almost always with color in the cheeks. He was, however, of strong will and great tenacity of purpose.

We have not been able to ascertain the date of his death.—(T. H. S.)

Nose, Relation of diseases of, to eye. See p. 1810, Vol. III of this *Encyclopedia*.

Nosebleed. Epistaxis. Hemorrhage from the nose. See p. 4500, Vol. VI of this *Encyclopedia*.

Nosepiece. A device for applying several objectives in rapid succession to a microscope without disturbing the focus.

Nosocomium. A hospital or an infirmary.

Nosology. That branch of medicine which treats of the distribution and arrangement of diseases into classes.

Nosophen-sodium. See **Antinosin,** p. 518, Vol. I of this *Encyclopedia.*

Nostoc commune. STAR-JELLY. FALLING STARS. An olive-green species of algæ often observed as round patches on gravel walks after rain. It was formerly held in esteem by the alchemists, and was used medicinally in gangrenous sores, cancer, etc., and in gout. In Siberia it is applied in ophthalmia.

Nota congenita. NOTA INFANTUM. NOTA MATERNA. Birth-mark.

Notation of lenses. See **Lenses, Numeration of,** p. 7407, Vol. X of this *Encyclopedia.*

Notched teeth. See **Hutchinson teeth,** p. 6068, Vol. VIII of this *Encyclopedia.*

Notch, Lachrymal. The notch in the edge of the orbital surface of the superior maxillary bone which receives the lachrymal bone.

Notch, Supraorbital. A notch near the middle of the supraorbital arch.

Note-blindness. A form of visual aphasia characterized by a loss of the power of recognizing musical notes by the eye.

Nothnagel's sign. Paralysis of the facial muscles, especially in respect of movements connected with the emotions: observed in cases of tumor of the thalamus.

Notops. Having spots resembling eyes on the back.

Novargan. See **Silver proteinate.**

Novargol. This is one of the numerous class of proprietary silver compounds. It is said to be a silver albuminoid containing 20 per cent. of silver in organic combination. It occurs in small shiny crusts which are readily soluble in cold water. The best results are obtained from a freshly prepared solution and it should be dissolved in cold water. Stock solutions undergo decomposition which give rise to irritation.

Novargol is germicidal and free from irritation. Of diseases of the eye it is used in purulent ophthalmia. The eye is flooded with a 25 per cent. novargol solution freshly prepared. It is claimed that ophthalmia neonatorum is prevented by a 25 per cent. solution, a few drops instilled into each eye followed by a warm boric acid solution.

Novarsenobenzol. A product of salvarsan and formaldehyd sulphoxylacid sodium. It is used like salvarsan, from which it differs in being neutral in reaction, less toxic, and more soluble. Called also "914."

Novaspirin. Anhydromethylene citric acid disalicylate; a white powder used like aspirin. Dose, 10-15 gr. (0.66-1 gm.). It is intended to replace aspirin in the treatment of rheumatic diseases. See p. 643, Vol. I of this *Encyclopedia.*

Novatopan. NOVATOPHAN. A proprietary, tasteless atophan preparation, thought to serve ophthalmic purposes even better than sodic salicylate.

Harold Gifford (*Ophthalmic Record*, July, 1914) has formed a high opinion of the value of atophan in the treatment of iritis and of sympathetic ophthalmitis. He had so far treated about twenty cases of the former and four cases of the latter disease by these means. He recommends a grain per diem for each pound of the patient's body weight, and in exceptionally severe cases, a third more. Whilst taking the drug the patients are confined to bed, at all events during the latter half of the day.

Gifford considers that atophan is fully as effective as the salicylates and their derivatives in all inflammations of the uveal tract. Its sole drawback is its present cost, namely, $1.50 an ounce, and novatophan 25 cents more.

Noviform. Tetrabromo-pyrocatechin-bismuth is put on the market by Merck under this name. It is a yellow powder, without smell or taste, having the chemical composition $Bi(C_6Br_4O_2)OH$, and containing an amount of bismuth corresponding to about 32 per cent. of bismuth oxide. It is insoluble in water and only slightly soluble in organic solvents, such as alcohol and ether.

According to V. Borovansky (*Medizinische Klinik*, 1912, No. 24, p. 992), noviform can be sterilized without decomposition in a current of steam, it is not poisonous when administered internally and, on account of the bismuth contained, it has a desiccating action, limits secretion and promotes granulation formation; while the tetrabromo-pyrocatechin content endows it with antiseptic properties. It therefore answers all the requirements of a good dressing for wounds.

L. v. Liebermann, Jr. (*Deutsch. medizin. Wochenschr.*, 1912, No. 11, p. 512), treated 25 cases of blepharitis with noviform in the form of 5 to 20 per cent. ointment (with vaseline). In ulcerative blepharitis this ointment may be spread on in a thin layer night and morning, after the scabs have been softened and removed. Existing conjunctivitis and follicular abscesses are treated separately. The ointment is also beneficial in blepharitis in the presence of blepharo-conjunctivitis, if the scales are previously removed. In simple squamous blepharitis or seborrhea sicca of the eye-lids, without demonstrable affection of the conjunctiva, the author obtained better results by the employment of noviform ointment than by the use of the customary remedies.

Bernoulli (*Brit. Med. Jour.*, July 17, 1915, abstracted from *Münch Med. Wochenschr.*, Jan. 12, 1915), is an enthusiastic advocate of the use of noviform in 3, 5, or 10 per cent. in various inflammatory diseases of the eye and its appendages. Usually diseases of the eyelids and cornea are treated by the general practitioner with boric lotion and yellow ointment. But since noviform was introduced in 1912 in the

treatment of these conditions it has deservedly displaced the older remedies in the opinion of many oculists. The author has used noviform for two years, and has found it act rapidly in cases of blepharitis which had proved refractory to weeks and months of treatment with boric lotion and white or yellow precipitate ointment. Both these ointments can, in fact, be dispensed with in the squamous and ulcerative forms of blepharitis, but the yellow ointment is still to be recommended for eczematous and phlyctenular conjunctivitis. Noviform is non-irritant, and as it causes no burning or pain, the patient can be trusted with it for home use. In chronic blepharo-conjunctivitis it is advisable to give the eye zinc baths before the noviform is applied in the form of a 5 to a 10 per cent. dilution in vaseline, which is applied two or three times a day. Eczema of the face, accompanied by eczematous conjunctivitis, rapidly disappears when treated with a 20 per cent. noviform ointment. Again, when foreign bodies have been removed from the cornea, the application of a 3, 5, or 10 per cent. noviform ointment reduces the risk of infection. Since he began using noviform, the author has seldom seen ulceration of the cornea follow the removal of a foreign body from the eye. In some cases it is advisable to combine the noviform vaseline with 1 per cent. of atropin, so as to hasten painless recovery.

Noviol. One of the numerous forms of tinted glass now on the market, intended to protect the eyes from glare or from injurious rays of light. Spectograms comparing this with other forms of protective glass will be found in the *Trans. Oph. Sec. A. M. A.*, p. 256, 1915. See p. 523, Vol. VII of this *Encyclopedia*.

Noviweld glass. This is a brownish glass with a greenish tinge. The proprietors claim that it cuts off all the ultra-violet and infra-red rays harmful to the eyes, and that it is particularly adapted for the use of oxo-acetylene and electric welders, or wherever protection is desired from intense, glaring flame of any kind. Spectograms comparing this with other forms of protective glass will be found in the *Trans. Oph. Sec. A. M. A.*, p. 256, 1915.

Novocain. A complicated organic compound introduced to supersede cocain, especially in hypodermic injections.

It was first fully described and recommended by Braun. It crystallizes in small colorless needles, is soluble in its own weight of water and melts at 150° C. There is no irritation from its use even in concentrated solution, and the cornea will stand the powdered drug. As the anesthesia from novocain is comparatively brief (and for this reason is not likely when used alone to be a serious rival of other anesthetics) it is suggested that it be employed hypodermatically with

the suprarenal alkaloids. Such a combination prolongs to a considerable extent its otherwise transient effects. The usual dosage ranges from one to ten per cent.

Gebb carefully studied the clinical and other actions of novocain and noted that it does not affect the width of the pupil in the less concentrated solutions. In 5 per cent. and 10 per cent. strength (exceptionally in 3 per cent.) a slight mydriasis is noted in the human subject after ten minutes. The duration of the dilatation varies; it may be very brief or persist over an hour. The dilated pupil always reacts to light and convergence. If suprarenin is added to 1 per cent. or 2 per cent. solutions of novocain in 1:1000 strength, a difference in pupillary width is obtained but without complete paralysis.

In the cases investigated novocain exerted no influence on the accommodation; even after the instillation of large amounts of the 10 per cent. solution, a reading test showed that the action of the ciliary muscles was not affected.

The advantages of novocain over cocain lie in its capacity for sterilization by boiling, in its negative action on the accommodation and, finally, in its being much less toxic. It is relatively non-irritating and the burning sensation produced does not constitute a contraindication. The same is true of the slight degree of hyperemia and mydriasis noted.

Nevertheless, novocain, even after addition of suprarenin, is inferior to cocain as an anesthetic for the eye.

Wicherkiewicz (*Wochenschrift für Therapie und Hygiene des Auges*, Feb. 14, 1907) has made some important observations of the use of novocain. The drug was used in 1 to 2 per cent. solution and the author noticed that novocain anesthesia is somewhat slighter, but comes on as quickly and lasts as long as cocain anesthesia. It has no influence on the pupil or accommodation, and does not reduce tension. On the other hand, it seems to delay the healing of the wound in cataract extraction. Novocain is specially suited for the infiltration method when the tissues are inflamed. Enucleation of a tender eyeball can be carried out painlessly. For this purpose he recommends the following solution: Novocain, 0.125; Suprarenin, 0.00016; Sodii chlorid., 0.225; Aquæ dest., 25.

Reinflet (abstract in the *Oph. Review*, p. 14, Jan., 1915, of *La Clinique Ophtal.*, March, 1914) considers that local anesthesia is quite sufficient for the *enucleation of even acutely inflamed eyes* if a proper technique is adopted. He states that in his experience the essential points are the use of sufficiently dilute solutions, the injection of a sufficiently large quantity and the necessity of waiting for a long enough period. The solution he recommends is: Novocain, 0.2 gr.;

adrenaline 0.1 per cent., 5 drops; sterilized physiological salt solution, 20 cc.

The solution must be freshly prepared, and boiling is not permissible after it is made up. Sterilized ampoules have not proved satisfactory as the presence of adrenalin appears to render the novocain inactive after a short period. The quantity usually injected is 4 cc. in two series of four injections.

The length of time necessary to wait is the capital point. Thirty minutes is the minimum. The more intense the inflammation of the globe the longer must the period of waiting be. The diffusion and absorption of the injection serves as a guide.

The anesthetization is conducted in three stages:—

1. Conjunctival anesthesia by instillations of novocain and adrenalin for a period of five minutes.

2. First series of four injections subconjunctivally at the insertion of each rectus muscle of half a cubic centimetre of the solution. During each injection, which is made slowly, the needle is gently pushed backwards in the line of the muscle. Then after five to ten minutes,—

3. Second series of four deep injections of half a cubic centimetre each with a strong curved needle about five centimetres long. The punctures are made in the same direction as in the previous series and situated at the bottom of the conjunctival sac. The needle is inserted deeply, encircling the globe to the back of the orbital cavity, and the injection forced into the retrobulbar region. There results from this an intraorbital and peribulbar edema which causes a certain amount of protrusion of the globe as well as some immobilization.

Before operating it is necessary to wait at least half an hour and in inflammatory conditions three-quarters of an hour may be necessary. The patient should be kept in the recumbent position during the whole period and for some hours after the operation is finished.

Reinflet has been so well satisfied with this method in even such cases as those of panophthalmitis that he has quite abandoned the use of a general anesthetic for enucleation.

For operations on the anterior segment of the eye he has adopted a modification of the above technique. He injects for this purpose the same solution only using one injection about ten millimetres from the limbus so as to avoid the production of a chemosis which might interfere with the operation. It is equally necessary, however, to wait for thirty minutes.

While we do not share the author's objection to general anesthesia

in the majority of enucleations, it is obvious that in those cases in which a general anesthetic is contraindicated this method should prove of great utility. See, also, p. 446, Vol. I of this *Encyclopedia*.

Van Lint (*Annales d'Oculist.*, June, 1914), to prevent contraction of the orbicularis palpebrarum during the performance of cataract extraction, partially paralyzed the muscle in question by injecting novocain and adrenalin into the terminal branches of the facial nerve which innervate the orbicularis. A tablet containing novocain 0.05 gr. and adrenalin 0.000,083 gr. is dissolved in 5 c.cm. of water or of physiological serum when it is about to be employed, or two ampoules of novocain 0.02 gr., adrenalin (1:1,000) i drop, sodium chloride 0.006 gr., and water 1 c.cm. are mixed with an equal quantity of physiological serum. Of this solution of 1 per cent. novòcain van Lint injects 3 to 4 cubic centimetres. The injection is made at two points. Partial paralysis of the muscle follows about twenty minutes after the injection has been made. The operation may be carried out from a half to one hour after the injection.

It must not, however, be forgotten that *novocain is an active poison* and that there are a number of cases on record emphasizing that fact. For example, G. Ricchi (*Rivista ital. di Ottal.*, Jan., 1909), has noted paralysis of the sixth nerve after injection into the spinal canal. This writer also noted 33 cases in the literature in which the cranial nerves were similarly involved.

Jassenetzky-Woino (*Zentralbl. f. Chirurgie*, July 8, 1911, p. 924) also reports transitory blindness after injection into the orbit of novocain-suprarenin.

Hatcher and Eggleston (*Journ. Am. Med. Assocn.*, Aug. 26, 1916), express the opinion that novocain has a distinct field of usefulness, but they call attention to the fact that death has followed the clinical use of small doses, and that toxic symptoms of varying degree of severity have been reported by numerous observers. Hence, while novocain is a valuable drug, it is not without its dangers, and the sooner these are understood and the better we are able to guard against them, the more useful the drug will be.

Novoform. A combination of bismuth oxid with tetra-pyrocatechin: used like iodoform.

Novoiodin. A proprietary disinfectant which is said, on contact with wound secretions, to liberate iodin and formaldehyd. Wicherkiewicz (*Rev. Gén. d'Opht.* XXX, p. 241, 1911) has advocated its local use in ophthalmic therapy.

Novorenal. The proprietary name given to a solution of novocain and adrenalin, sterilized and sold ready for use in sealed ampullæ. The

composition of the solution varies according to the particular purpose for which it is used, but the solvent in most instances is physiological salt solution, and it evidently belongs to the same class as capren, codrenin, etc.

Noxa. An injurious agent, act, or influence.

Noyes, James Fanning. A pioneer American ophthalmologist. Born at Kingston, R. I., Aug. 2, 1817, he studied medicine at the Harvard Medical School and at the Jefferson Medical College, at the latter institution receiving his degree in 1846. For a time he was assistant physician at the U. S. Marine Hospital at Chelsea, but settled at Waterville, Mass., in 1849, and in Cincinnati in 1851. Turning his attention to ophthalmology, he studied in Berlin in 1855, in Vienna in 1856, and in Paris in 1858 and 1859. Returning to America, he settled as ophthalmologist and otologist in Detroit, Mich., where he soon had a large practice and became professor of ophthalmology and otology in the Detroit Medical College. He invented the Noyes operation for strabismus and a number of ophthalmic instruments. He never married. His death occurred at Providence, R. I., in 1896.—(T. H. S.)

Noyes, Henry Dewey. A famous American ophthalmologist, author of the well known textbook, "*Diseases of the Eye.*" Born in New York City in 1832, he received the degree of A. B. from New York University in 1851, the A. M. from the same institution in 1854. Turning his attention to medicine, he received the degree of M. D. in 1855 at the College of Physicians and Surgeons in the City of New York. After three years' service on the residence staff of the New York Hospital, he spent a year in England, France, and Germany, as a student of diseases of the eye and ear. Returning to America in 1859, he settled as ophthalmologist and otologist in his native city. He was for many years on the staff of the New York Eye and Ear Infirmary; assistant ophthalmic surgeon from 1859 until 1864; ophthalmic surgeon from 1864 until 1900; executive surgeon and consulting surgeon from 1875 to 1898. In the Bellevue Hospital Medical College he was professor of ophthalmology and otology from 1868 to 1892, and of ophthalmology alone from 1892 to 1900. One of the founders of the American Ophthalmological Society in 1864, he was also the first secretary of that body, a position which he held till 1874. He was president of the same society from 1878 to 1884.

He died of pneumonia at his summer home in Mt. Washington, Mass., Nov. 12, 1900, aged 68. A widow and three children survived him.

Dr. Noyes was a small, thin man, of nervous type, abrupt and rapid in all his ways. Though his somewhat brusque manner belied his really

generous and self-sacrificing tendencies, he was universally respected and esteemed for his operative skill and for his positive genius as an organizer and all-round man of affairs. As the writer heard him remark one day to an assistant who had been a trifle hurt at one of the doctor's apparent rudenesses, he was "too busy to be kind."

Dr. Noyes was not a frequent contributor to periodicals, but his text-book, above referred to, was one of the best which, up to and including its day, had appeared in any language. The first edition of this excellent work was published in 1890, the second in 1894.

He was, also, the inventor of a number of useful and ingenious ophthalmic instruments and appliances that bear his name and that are still widely used.—(T. H. S.)

Nuance. A slight variation or delicate shade of difference.

Nubecula. NEBECULA CORNEÆ. A small, faint opacity (of the cornea).

Nubilous. Cloudy.

Nuclear cataract. An opacity of the lens which begins in the nucleus. It is generally of moderate extent and is surrounded by more or less transparent lens substance. The nucleus is usually fine and yellow, not really opaque, but very hazy. See **Cataract, Nuclear,** p. 1567, Vol. III of this *Encyclopedia.*

Nuclear paralysis. A term generally applied to (oculomuscular) paralyses or pareses due to affections of the nuclei of the eye muscles, situated at the base of the third ventricle, in the aqueduct of Sylvius, and on the floor of the fourth ventricle. See **Muscles, Ocular.**

Nuclear stains. See p. 6908, Vol. IX of this *Encyclopedia.*

Nucleide of mercury. See **Mercurol,** p. 7648, Vol. X of this *Encyclopedia.*

Nuclei of ocular nerves. See **Neurology of the eye**; also p. 6551, Vol. IX of this *Encyclopedia.*

Nucleotherapy. The treatment of disease with nucleins from blood-serum and from various glands.

Nucleus. As applied to the central nervous system, a more or less clearly defined mass of gray or ganglionic matter. Instead of nucleus, the terms *nidus, nidulus, nest corpus, locus, ganglion* and *centre* are sometimes used; and unless otherwise stated, these are usually symmetrical or paired, appearing on the two sides. See **Intracranial organs of vision.**

Nucleus, Abducens. The nucleus of origin of the abducens nerve, a gray mass within the lower part of the pons, near the floor of the fourth ventricle.

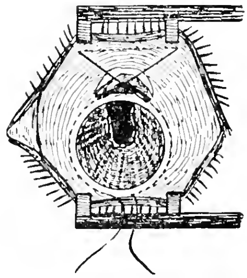
Nucleus lentis. (L.) The nucleus of the crystalline lens.

Nucleus, Oculomotor. The nucleus of the oculomotor nerve, under the aqueduct of Sylvius.

Nucleus, Spitzka's. One of a group of oculomotor nuclei in the cinerea below the aqueduct of Sylvius.

Nucleus, Westphal's. A small gray nucleus beneath the aqueduct of Sylvius: the origin of some of the fibres of the trochlear nerve.

Nuel stitch. In scleral ruptures concentric with the cornea Nuel's method (see the cut) of stitching will be useful. A thread armed with



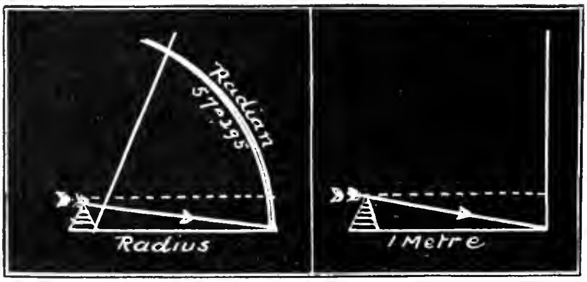
Stitch for Scleral Rupture. (Ball after Nuel.)

two needles is passed beneath the conjunctiva near the equator and is made to encircle the cornea. When tied, it causes the lips of the scleral wound to approximate. Atropin is then instilled, a bandage is applied, and the patient is confined to bed. If infection occurs, the case will probably require enucleation; if infection does not occur, useful vision may be saved.—(J. M. B.)

Number-blindness. See **Visual aphasia**; as well as **Neurology of the eye.**

Numbering of lenses. See **Lenses, Numeration of,** p. 7407, Vol. X of this *Encyclopedia.*

Numbering of prisms. Formerly prisms were numbered by their re-



Centrad and Radian.
Prism-dioptre and Metreplane. (Ball.)

fracting angles. In recent years two improved methods have come into general use: (1) the centrad method of Dennett, and (2) the prism-dioptre method of Prentice. In the former unit, or centrad ($\bigtriangledown$), is a prism which deviates a ray of light 1/100 part of the radian. (The radian is the measure of an angle subtended by an arc equal in length to the radius. It is equal to 57.3°.) The figure shows both the centrad and the radian.

In the latter method the unit is that prism (called a prism-dioptre) which, placed 1 metre from a tangent, will cause a ray of light to deflect 1 centimetre on the tangent.—(J. M. B.)

Numeration of lenses. See **Lenses, Numeration of,** p. 7407, Vol. X of this *Encyclopedia.*

Numerical aperture. The product of the sine of half the apical angle of the maximum cone of light, which a microscope objective can take up from an axial point of an object, and the refractive index of the medium in which the object is immersed. See, also, **Aperture,** p. 533, Vol. I of this *Encyclopedia.*

Nummular keratitis. A synonym of superficial punctate keratitis. See p. 6814, Vol. IX of this *Encyclopedia.*

Nunnely, Thomas. A well-known English surgeon, who enjoyed an especial reputation as an operator for cataract. Born in 1809 at Market Harborough, he studied at Guy's Hospital, London, under Key and Sir Astley Cooper, and in Paris under Laennec. Settled in Leeds, he became in 1835 physician to the Leeds Eye and Ear Infirmary, a position which he held until 1864. In that year he was appointed surgeon to the Leeds General Hospital. He is said to have been an operator of very remarkable dexterity. He died at Leeds June 1, 1870.

Nunnely's more important ophthalmic writings are: 1. On the Organs of Vision, Their Anatomy and Physiology. (London, 1858.) 2. On the Employment of Alkaloid of the Calabar Bean in Prolapsus of the Iris. (*Lancet*, 1863.)—(T. H. S.)

Nursing, Ophthalmic. It is the duty of the ophthalmic nurse in the hospital to perform, personally, all the nursing necessary in her department. Under no circumstances should a nurse having charge of contagious cases, come in contact with operative cases, for obvious reasons. The ophthalmic nurse should always be on hand to make the rounds with the attending surgeon and interne, and should carry with her a tray upon which is placed everything which is necessary for the daily dressing of the patients. She should be able to vouch for the cleanliness, sterility and freshness of everything upon her tray and

should give this matter her personal and earnest attention, remembering that while in general surgery a little suppuration in a wound need not necessarily prove disastrous, in ophthalmic surgery, particularly in cataract operation and iridectomies, perfect healing must be secured, as the slightest infection will almost certainly bring ruin in its train.

An important feature in duties of the ophthalmic nurse is to acquire the knack of putting solutions and ointments into the conjunctival sac, and irrigating or cleansing the eye without injuring it, and of properly adjusting a bandage. She should understand how to use hot and cold applications; these and many other things so trifling as to appear insignificant and yet of great importance if the best results are to be obtained. The ophthalmic nurse should attend the surgeon when he performs operations. She should prepare the patient for operation and should have all dressings ready for application after the operation. In the operating room she should wear a gown which completely covers the body, and some sort of head dress which thoroughly envelopes all parts except the face. In special cases where the nurse is intimately associated with the operation, she should wear mask and gloves to complete logically her costume. One great advantage in the teaching of ophthalmic nurses in this way is the education of women in this line of work, so that after graduation surgeons can secure their services in private cases treated at home.

In some hospitals—St. Luke's, Chicago, for example—the ophthalmic nurse is a *permanent* official, and only her assistants are changed every few weeks, as in the ordinary training school. This is the crux of the situation; when the only nurse available for the care of ophthalmic cases is an untrained and transient follower of the curriculum of a training school she is usually of little assistance—in fact generally a source of annoyance and danger—to the surgeon. A permanent nurse, on the other hand, is one with important responsibilities—curator of the instruments, instructor of assistants, minor operator, etc.—of great value to patients and immense relief to the busy hospital attendant.—(C. P. S.)

Nussbaum, Johann Nepomuk. A famous German general surgeon and ophthalmologist. Born at Munich Sept. 2, 1829, the son of a ministerial secretary, he received the degree of Doctor of Medicine at the Münchener University in 1853. His dissertation, on this occasion, was "Ueber Cornea Artificialis." After a year of surgical and ophthalmological study in Paris and other foreign cities, he settled as surgeon and ophthalmologist in Munich. He wrote almost 100 books and articles, of which the most important were "*Behandlungen der Hornhauttrübungen mit Besonderer Berücksichtigung der Einsetzung einer*

Künstlichen Hornhaut" (1857) and "*Leitfaden zur Antiseptischen Wundbehandlung*" (Five eds. from 1877 till 1889). He died Oct. 31, 1890.—(T. H. S.)

Nutmeg. The kernel or nucleus of the seed of various species of *myristica,* especially *myristica fragrans (officinalis).* The kernel of the ripe seed and the expressed oil or butter are mostly used in medicine, and when taken in quantity are sometimes poisonous. In a few recorded instances the toxic symptoms were found to be sleepiness, vertigo, headache and stupor, with various forms of disturbed vision, especially amblyopia and transitory amaurosis. A woman who had taken four nuts had these symptoms, especially dizziness, stupor and complete blindness. The toxic condition remained for two and the blindness four days. Complete recovery occurred later.

Hemiopia has been mentioned as one of the visual signs, together with marked mydriasis and absence of reaction to light.

In another case where three nuts were eaten complete collapse and cyanosis set in, followed by widely dilated pupils and marked exophthalmus.

Nutrition of the eye. This subject has already been discussed under various headings in this *Encyclopedia,* but particularly under **Circulation of the intraocular fluids,** p. 2256, Vol. III, to which the reader is directed. An admirable review of the whole subject is to be found in Parson's *Pathology of the Eye,* Vol. III, pp. 996 to 1027.

Angelucci *(Twelfth Internat. Congress of Ophthal.,* 1914; Abstract, *Ophthalmoscope,* p. 75, Feb., 1915) deals with the phenomena of intraocular exchange, the physical and chemical properties of the aqueous, the rate of its production, the factors which influence its secretion, and the pathological disturbances of these phenomena. Under the head of the physical and chemical properties of the aqueous, attention is drawn to recent researches into its molecular concentration or osmotic pressure, its electric conductivity, its viscosity, etc., researches for which we are chiefly indebted to Italian observers. Among the factors whose effects in modifying the constitution and properties of the aqueous are discussed, we find paracentesis, the application of mydriatics, myotics, anesthetics, and other drugs, cauterization of the cornea, subconjunctival injections, irritation of the cervical ganglion, sympathectomy, and states of the fifth nerve.

Discussing the rate of exchange of the aqueous, Angelucci accepts the statement of Leber and Niesnamoff, that this amounts to 5 cub. mm. per minute. His views as to the mechanism of the formation of the aqueous is that in the ciliary body lymph leaves the vessels by a process of transudation, which includes both filtration and diffusion, and

that the lymph so formed is converted into aqueous by a quantitative change produced by the epithelium of the ciliary processes.

Nux regia. See **Walnut, English.**

Nux vomica. Quaker buttons. Poison nut. This remedy is the dried, ripe nut of *Strychnos nux vomica,* a plant of Asia and Australia. It contains strychnia, brucia and other alkaloids, is a powerful poison, motor excitant, cardiac and nervous stimulant, in doses of from one to five grains. Dose of the tincture 5-15 drops. Its medicinal effects are mostly due to the strychnia it contains. See **Strychnia.** The fluid extract and the tincture are often employed as a nervine tonic in the treatment of toxic amblyopia and optic atrophy.

The use of the tincture in increasing doses is of extreme value in all cases of muscular imbalance. In particular, they show results in those instances dependent upon weakness of the nerve supply. de Schweinitz first advocated this method of treatment and advised that the dose be increased to the point of its toxic effect.

Nyctalope. A person affected with nyctalopia.

Nyctalopia. Nyctalopiasis. Night-blindness. A form of visual affection in which the sensibility of the retina to light is diminished. If we adhered to the strict derivation of the word, nyctalopia should signify night-vision, or day-blindness, as being the opposite condition to that of hemeralopia. Common usage, however, has decreed that the terms nyctalopia and hemeralopia should express the condition of night-blindness and day-blindness respectively. See, also, page 3777, Vol. V of this *Encyclopedia.*

The expression, *nyctalopia*, has had its own peculiar history. By Hippocrates it signified "day-blindness." By Galen it meant either "day-blindness" or "night-blindness." The Post-Galenic writers, until the beginning of the Renaisance, followed, as a matter of course, the powerful example of Galen. Since the Renaisance, the term has been almost (but not quite) exclusively employed in the original Hippocratean sense. The matter is all the more confusing, because, by Hippocrates, the word was oftenest used in the sense of mere photophobia. The fundamental cause, however, of the hopeless ambiguity of this term would seem to lie in the fact that the word possesses a two-fold etymology: meaning, in fact, according to the one derivation, "night eye," and, according to the other, "night-blind eye."

"Hemeralopia" is altogether modern. Nevertheless, by a reversed analogy with nyctalopia, its meaning is rather ambiguous. Thus, for example, so high an authority as Quain uses "nyctalopia" in the sense of "night-blindness," and "hemeralopia" in the sense of "day-blindness."—(T. H. S.)

Parsons *(Lancet,* Feb. 22, 1908) regards nyctalopia as dependent upon some defect in the rods or connected with the function of the visual purple. That of retinitis pigmentosa he thinks closely allied to congenital stationary night-blindness; while syphilitic pigmentary retinitis may stand between the two. Acute night-blindness is associated with defective nutrition, as with scurvy, malaria, nephritis, jaundice and anemia due to poor diet. In these cases the visual purple may be restored more slowly than normal. Central vision in nyctalopia is obscured, the patient seeing as through a cloud. The accompanying symptoms are contraction of the field for white, reduction in central quantitative color-vision, dread of light, undue dilatation of the pupils under reduced illumination, paresis of accommodation, erythropsia, xanthopsia, and epithelial xerosis. Nyctalopia, according to Snell, has been observed endemically among malarial subjects, scorbutic sailors, and among children in the public schools. Sleeping in the moonlight is said to be a cause.

The present world war has furnished exceptional opportunities for studying this condition. Among 10,000 patients at one military eye hospital, 140 cases of nyctalopia or night-blindness came under the observation of Birch-Hirschfeld *(Jour. A. M. A.,* Dec. 23, 1916). In 108 instances the disease was present before the war began, in most of these cases having existed since early youth; but military service seems to have caused greater disturbances than did civil life. In thirty-two cases the condition was noted first during military service. In nine cases an injury, followed by hemorrhage, in five cases intestinal disease, and in three cases light dazzling (Blendung) were recorded as being the exciting causes. Myopia was present in sixty cases, to the extent of more than 6 diopters in twenty-six of these. It is assumed, therefore, that myopia is a cause of nyctalopia. A hereditary influence was traced in one-third of the cases. Central vision was approximately normal in sixty-three cases, fair in sixty cases and considerably disturbed in seventeen cases. The fundus was normal in sixty-eight cases; in thirty-eight cases the peculiar pigmentation first described by Augstein was present, and in twenty-seven cases there was a deficiency of pigment. In seven cases there was a peripheral chorioretinitis. In the majority of cases the visual field for blue was considerably narrowed, especially in subdued light; thirty-three times for white and blue, even in ordinary daylight, and twenty-eight times there was a reduction of more than 30 per cent. Blue spots on a gray background remained invisible to the nyctalopes after half an hour of rest in the dark longer than to the normal eye. A five point adaptometer, devised by Birch-Hirschfeld, proved to be of great value in the

examination of these soldiers. It was found that in the nyctalopes the irritation threshhold frequently is higher than in the normal eye, in many cases following slight disturbance of adaptation. and that the adaptation may be diminished with a normal irritation threshhold. In ninety-two cases both types of disturbance were present. They occurred particularly in the older patients with fundus changes and a reduction of central vision. Forty-nine patients were under observation for several weeks; in only eight cases was there any marked improvement, and six of these were recent cases. Birch-Hirschfeld emphasizes that it is impossible to make a definite prognosis in these cases after a single examination; therefore it is greatly to be desired that these patients remain under observation for several weeks, preferably in a hospital. The treatment consists, in the main, of increasing the resistance of the patient by the administration of tonics and protecting the eye from the light. Reduction in visual acuity and definition of not more than one-fourth does not incapacitate the patient for military service, but he should be kept under observation all of the time by the army surgeon, and he should not be subjected to night duty of any sort. Only in exceptional cases should nyctalopia be considered as an adequate reason for granting a pension. Nyctalopia is not a specific disease or disease entity. Many factors are operative in its production. As a rule, the acute form is easily differentiated from the chronic sporadic form. In the production of the acute form, loss of blood, emaciation, faulty nutrition and poisons play a rôle. Light dazzling usually initiates the attack. The prognosis is usually a favorable one. In the production of the chronic form one must consider heredity, local conditions, such as developmental errors in the retina and choroid, and myopia, although nutritional disturbances and toxins may be contributing factors. Birch-Hirschfeld does not agree with Paul that nyctalopia bears any relationship to neurasthenia. Careful examination of these cases confirms the belief that the disease is essentially an organic disturbance of the retina.

In regard to *treatment*, the use of cooked liver and of cod-liver oil have for a long time enjoyed a great and deserved popularity among the laity. In addition the nutrition should be strengthened by diet and corroborative remedies. The eyes should be protected from light by the use of dark glasses, or in the severer cases. the patient should be kept in a dark room for a few days. By this treatment the duration of the condition is shortened.—(C. P. S.)

Löhlein (*Wiener Medizinische Wochenschrift*, 1916, p. 1242) maintains that the term night-blindness does not apply to the nocturnal

disturbances of vision observed in the field of war, for various reasons. In testing hemeralopia with the light dial it is desirable in the interest of the accuracy of the results to make the same test upon a control person with normal dark accommodation. It is recommended that the control person be given the same vision by day (through putting on glasses which lessen vision) as has the patient to be tested. Among those called night-blind are found a large percentage of cases in whom no hemeralopia exists; and the disturbances of vision are explained by states of nervous exhaustion, arterio-sclerosis, alcohol and tobacco poisoning, migraine, etc.

As far as cases of actual hemeralopia are concerned, that is, cases in which the power of dark accommodation is diminished, it is easy to show that the patients were aware that they had inherited or acquired hemeralopia of a high degree; or—and these are a large majority—who observed from the first day they were stationed at the front, their defective dark adaptation, and in whom this tendency had not come to their knowledge because of the conditions of life during a time of peace. Seldom did one find a real case of hemeralopia arising on the field; and in such cases there was always a pre-existent ocular or general disease which had already been recognized in time of peace as a cause or accompaniment of hemeralopia. Among the night-blind of the eye-station of one army corps, no special case of war-hemeralopia had been received. Above all in each single case it is necessary to determine clearly the cause of the nocturnal visual disturbance.

As far as the not very frequent cases of acquired hemeralopia are concerned, the removal of the primary disease will also influence the severity of the hemeralopia. On the other hand, radical treatment promises no result to people afflicted with deficient dark accommodation. Patients having the highest degree of this disability can only be used, for purposes of war, in very special occupations. Those with a medium degree, at least those on patrol duty, should be exempt from night reconnoitering and driving. In general when night-blindness is not responsible for the visual disturbance, and states of nervous exhaustion and similar conditions are, improvement of the primary disease promises relief of the disorder.

Nyctalopiasis. (Obs.) Day-blindness.

Nyctanthes arbor tristis. Indian mourner. Sad-tree. The *singahar* of the Bengalese, the *hursinghar* of the Hindoos. The flowers furnish a dye, and from them a distilled water is used as an eye-wash.

Nyctopie. (F.) Nyctalopia.

Nyctotyphlosis. Nyctalopia.

Nymphæa pubescens. East Indian lotus. This plant is indigenous

to Africa, the East Indies, and Java. In the East Indies a decoction of the root, which is edible, is employed in dysuria and hemorrhoids, and the leaves, in the form of a salve, are used in eye diseases.

Nystagmic. Pertaining to or characterized by nystagmus.

Nystagmograph. An instrument for recording the movements of the eyeball in nystagmus.

Nystagmography. The measurement and study of nystagmus by graphic methods. The student of this subject is referred to the section **Nystagmus** in this *Encyclopedia* and to the article by Buys on nystogmography in man in the *Révue Générale d' Ophtalmologie,* for Feb., 1911.

Nystagmus. *Nystamus in general.* This term is applied to a condition in which there is a very rapid, short and tremulous to-and-fro movement of the eyeball, due probably to some perversion of the centres governing the co-ordinate movements of the eyes, rather than to any trouble with the muscles themselves, or with their supply nerves. Both eyes are almost always affected, and, moreover, are affected precisely alike. The eye makes from one to three oscillations a second, each oscillation being from 1 to 4 mm. in length. The oscillations may be horizontal, vertical, or rotary. In so-called mixed nystagmus, oscillations of different kinds are combined. Bilateral nystagmus is usually horizontal, although the rotary form is fairly frequent. Vertical nystagmus is rare, but on the other hand when the nystagmus is unilateral, it is almost invariably vertical. When the eyes are carried in some special direction, the nystagmus often increases, and decreases when they are carried in some other direction. It decreases at times when the eyes are converged. There are two varieties of nystagmus: 1. In those who from birth or from very early childhood have suffered from some condition which has produced marked impairment of vision in both eyes, such as congenital cataract, corneal opacities, albinism, or some disease of the fundus. 2. As a late acquired affection in diseases of the nervous system, such as disseminated sclerosis, hereditary ataxia, and cerebellar disease. Also in labyrinthine disease of the ear, or disturbance of equilibrium.

Another variety of nystagmus, called miner's nystagmus, is found among coal workers, who labor under poor illumination, and in a position which requires them to strain their eyes by constantly looking upward and backward. See **Miner's nystagmus,** p. 7834, Vol. X of this *Encyclopedia.*

A congenital form of nystagmus, unassociated with other gross disorder, has been seen in four generations, and often in three. Inheritance may be discontinuous. Burton saw in one generation only males,

and in another only females affected. Cases of albinism sometimes show only nystagmus without albinism in certain members of the family (Parsons).

Coppez (*Archives d'Ophtalmologie,* September, 1913; abstract in *Oph. Review,* p. 172, June, 1914) divides nystagmus into two main varieties, "spring" nystagmus and undulatory nystagmus. The curve of the first as registered by the apparatus of Buys presents a sharp, sudden upstroke and a slow, uniform descent with one or two notches and plateaus. The curve of the second shows none of those features but both phases have the same rapidity. Coppez states that the pathology of the two varieties is quite different.

1. *Pathology of "springing" nystagmus.* Vestibular nystagmus may be taken as the type of this variety. He describes the connections of the vestibular nerve and demonstrates that it is in connection with all the body musculature to the tone of which it contributes. If the vestibular nerve on one side is cut in the rabbit, the tone of the opposite side diminishes or disappears. In such an experiment, the harmony between the two vestibular nuclei being broken, the animal turns on itself and the eyes would follow suit but for their anatomical limitations. The globes are quickly arrested in their turning movement, and the only method of prolonging the rotation which the vestibular lesion causes is to make a retrograde movement so rapid that it escapes consciousness and then to start a new deviation. Subjectively the rotation appears in this way to be continuous.

As regards the intimate mechanism of the two phases as each vestibular apparatus acts at the same time on each of the four lateral muscles by the contraction of two of them and the relaxation of their antagonists, it is necessary to admit the existence of a tonic co-ordinating centre. This may be found in those cells of Monakow in the neighborhood of the sixth nerve nucleus. This serves to explain the slow part of the nystagmus. The rapid part is not so easy to explain. Coppez suggests that this phase starts in the muscle itself. The excitation is transmitted either through the trigeminal nerve or by Sherrington's sensory fibres in the motor nerves and reaches a centre of rhythmic co-ordination. This centre is not the same as that for tonic co-ordination, in fact the two phases may be dissociated. The sharp phase is suppressed before the slow one in chloroform narcosis simultaneously with the pupil reflex. The rhythmic centre should thus be found nearer the voluntary centres.

It is further necessary to admit, as Buys does, that the tonic centres of the two sides react on each other. In this way hyperfunction of one centre is accompanied by hypofunction of its fellow. This explanation

will cover such nystagmus as that which follows sudden loss of function of the cerebral cortex on one side, for it is obvious that the tonic centres receive not only vestibular but also cortical, retinal and auditory impressions. Such nystagmus is sometimes called vestibular but should rather be called supravestibular or nuclear.

2. *Pathology of undulatory nystagmus.* Since the tonic association centres act on the rhythmical centres through the periphery as intermediary, each time that an association centre receives an abnormal stimulus, the eyes deviate and tremble if the stimulus is sufficiently energetic or persistent. But the rhythmic centres may enter into activity from causes independent of the tonic centres. There is then a nystagmus without any question of conjugate deviation and no slow or rapid phase.

This is the type of miners' nystagmus. This is really an incomplete tetanus. The muscular super-excitation which accompanies the fatigue extends equally to the rhythmic centres and stimulates them abnormally.

In associated nystagmus, in certain varieties of nystagmus associated with lesions of the central nervous system, as in spasmus nutans, there is simply abnormal stimulation of the oculo-motor nuclei and the rhythmic centres associated with them.

In a paper on *hereditary nystagmus,* based on nine published cases and four new pedigrees, Nettleship (*Ophthalmic Review,* June, 1911) divides them into two groups: 1. Nystagmus associated with head movement, with affection of males and females and continuous inheritance of the defect. 2. Nystagmus with no head movement, with affection of males only (there were certain doubtful exceptions) and inheritance through the unaffected females. The inheritance in these cases was similar to that recognized for color-blindness and hemophilia. In the first group the nystagmus was horizontal; it varied greatly in rapidity and extent. The head movement tended to diminish with age. In both groups the affected had poor vision and marked ametropia, usually hypermetropic astigmatism, many had albinotic characteristics. There was no evidence of general nerve disease, and no consanguinity.

Casper observed nystagmus in five relatives—three brothers and two cousins, all males. Lanz observed the same anomaly in members of five generations. Dudley reports 26 nystagmic individuals out of 47 in four generations of a family in which intermarriage had frequently taken place, though consanguinity was not present in all the subjects affected with nystagmus.

Wilson (*British Medical Journal*, November 22, 1913) has devised an ingenious method of studying the comitance or otherwise of nystag-

mus. Two 12 degree square prisms are placed edge to edge and interposed between the observer and the patient. By moving the appliance nearer to or farther from the patient, the eyes are seen to approximate and to separate, and a distance can be selected at which the corneæ are seen edge to edge, when the movements of the eyeballs can be studied. In order to obtain magnification, it is convenient to place on the patient's face a trial frame armed with a + 20 D. spherical lens in front of each eye.

Diagnosis of low degrees of nystagmus. As Edward Jackson *(Ophthal. Review,* Jan., 1910) points out, high degrees of nystagmus are easily noted and on account of the movements many patients seek relief. Pronounced excursions of the eyeball, 2 mm. or upward, can be measured with sufficient accuracy by holding a rule in front of the eye, or noting the movement of the eye with reference to the reflex from a fixed light. Low degrees of nystagmus, excursions of 1 mm. or less, are more difficult to measure; and sometimes it is not easy by ordinary examination to decide whether or not nystagmus is present. Nystagmus of low degree is probably more frequent than nystagmus of high degree, and is of equally important significance. Most ophthalmologists have observed, while making the ophthalmoscopic examination, low degrees of nystagmus that have not before been noted. Direct ophthalmoscopy, in which we watch the highly magnified image of the ocular fundus, will furnish a simple and sufficiently exact method for measuring the extent of the nystagmic movements.

The method consists in noting the character of the movements executed by definite structures in the ocular fundus as seen in the erect ophthalmoscopic image. Withdrawing the observer's eye until the optic disc appears to occupy the whole of the pupil one observes the apparent extent of the movements, whether a given vessel appears to pass entirely across the width of the pupil with each excursion of the eyeball, or only one-half or one-fourth of that distance. From this, by brief calculations or from the tables given, the real extent of lateral or vertical movement is to be deduced. Perhaps it is not necessary that all cases of nystagmus shall have the extent of movement exactly measured. Yet this can properly be required for cases reported to take their place in the literature of the subject; and it will be found very satisfactory, in attempting to judge by the extent of the movements, as to the progress of any case under treatment.

In a discussion on nystagmus before the Royal Society of Medicine, Spicer *(Ophthalmic Review,* May, 1914) traced the history of our knowledge of the condition, and showed that the movements of the eyeballs varied from large and obvious excursions down to movements

only perceptible by the ophthalmoscope. In nearly 50 per cent. of 200 cases he found that the movements were in a horizontal direction; in about 15 per cent. rotary, in about 12 per cent. vertical, in 4 per cent. mixed, in 2 per cent. irregular, in 2 per cent. circumductory, and in 1 per cent. were condivergent or disjunctive. The horizontal and vertical forms varied greatly in rapidity of movement and in range, and were nearly always conjugate, but in a few cases they were condivergent. The rotary cases were nearly always conjugate, but condivergent ones had been seen. Circumductory movements were usually conjugate; he had never seen one which was not. They were often rhythmical. Use of the eyes was essential to the existence of nystagmus. The eyes were quiet during sleep, and sometimes so in the dark. It sometimes happened that on covering one eye, oscillations commenced in both. Unilateral nystagmus was not uncommon, and the movements were usually vertical, but not always. If the nystagmus had been recently acquired, a sensation of movement of objects was produced, but this was never noticed in the congenital cases. Nystagmus did not occur in those born blind, or who became so very soon after birth. It often became more marked with fatigue; in some cases light produced it, and in some it became more apparent in the dark. Some persons were able to produce nystagmus at will. The most important causative factor was a defective retinal image, due to either a corneal or a lenticular lesion or to some abnormal nerve or retinal condition. Errors of refraction had not been proved to cause this, but corrections of high degrees of astigmatism had often led to great improvement, or even to cessation of the nystagmus. Many of these patients had large refractive errors. Albinos and those with excessive pigmentation often had nystagmus. The pigment which affected eyes in this manner was usually supposed to be that of the retinal epithelium, but this could not be recognized by the ophthalmoscope, as the choroidal pigment masked it, and this might really be the case in those which were not obviously albinotic. In some cases the nystagmus was hereditary, but its cause not definitely ascertained. As regards occupation nystagmus, the weight of evidence was on the side of bad fixation being the primary cause, and besides miners, compositors were often affected. In spasmus nutans the head movements preceded the nystagmus by a few weeks, and they bore no relation to each other. The condition was supposed to be due to an instability of the motor centres.

Wilfred Harris contends nystagmus should not be assumed to exist unless the lateral movements were persistent and rhythmical during the test; the observer should also determine whether the nystagmus was a symptom of cerebro-spinal disease, or was of ocular origin.

Cases which did not belong to either of these groups, such as head nodding, should also be recognized, and in the last-named form usually only one eye was affected. If, in early infancy, macular development was interfered with, such as by anterior polar cataract, so that there was not a clear image on the fovea, the cerebral co-ordination was not brought into play to keep the eye rigid, hence there were constant oscillatory movements. Ocular nystagmus might be said to be due to disease of the afferent path concerned with the reflex for fixation of the eyeballs. Occasionally in adults nystagmus might be due to defect of vision, and it might be uniocular. In nystagmus of central origin, the symptom was brought out especially on deviation of the eyes laterally or upwards, and was not apparent on fixation in the median line. Most intense nystagmus was occasionally set up by a tumor of the cerebrum, especially if the optic thalamus were involved by it. He mentioned cases of this, and recalled that Gowers made the same observation. The value of nystagmus for cerebral localization was not great, but it was usually suggestive of cerebellar disease. The most intense nystagmus might be an accompaniment of sub-tentorial disease.

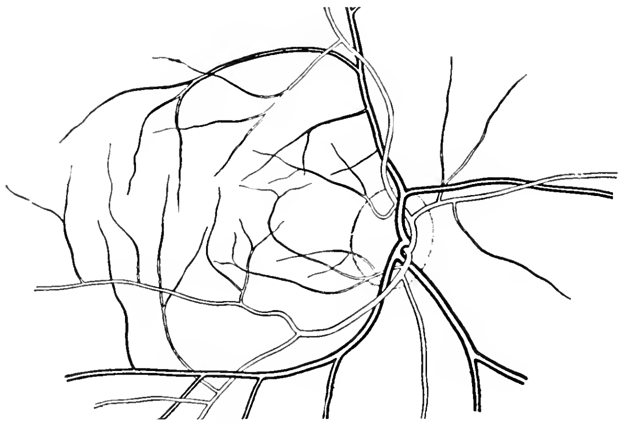
Abrahams uses cinematographic records of nystagmoid movements. He said the human eye was a very capable nicrometer, and was capable of appreciating a movement which the camera did not reveal. Some of the movements photographed were less than 1/10th of a millimetre, and pictures were taken at the rate of 25 to 30 per second. Miner's nystagmus was too fine to photograph.

Layton notes that there are great differences of opinion as to the value of vestibular nerve tests, including nystagmus, in the diagnosis of nerve diseases. He has raised the question as to how much of failure to correctly perform co-ordinate muscle movements was due to withdrawal of cerebral control, and how much to defect of the vestibular nerve. In a certain number of cases, vestibular reaction when correlated with evidence obtained from other sources would enable one to clinch a diagnosis, or detect a gross lesion which otherwise would seem equivocal. Every neurologist should learn to do these tests, or send their patients to otologists who could do so.

Rugg Gunn mentions nystagmus as it affects albinos. In diseases of the retina associated with degeneration of the rods, there was the converse condition to night-blindness. An eye in that condition looking at the spectrum of sunlight, found the red end shorten and disappear, while its broadest portion appeared to move towards the violet end. It occurred to him that if in the albino the cones were found to be functionless, this absence of function in the fixation point was a

sufficient cause for the nystagmus, and also, perhaps, for the intense photophobia found. Such a person would be dark-adapted. He described the case of an albino, one of nine observed, in which this was so. See the figure.

The rather rare anomaly of a *unilateral vertical nystagmus* is reported by Zentmayer (*Ophthalmic Record,* April, 1911) in a 17 year old patient. He describes the case thus: The eye has been turned for 12 years. As long as he can remember, objects looked at "jumped."



Distribution of the Retinal Vessels in the Central Area of the Fundus in Albinotic Eyes with Nystagmus. (Ichikawa.)

He never had diplopia. He has worn glasses five years. He has one brother and one sister, but neither has any eye trouble.

There is an esotropia of 40 degrees, measured on the perimeter. The right eye is the fixing eye. In the left eye there is a vertical nystagmus. The movements are short, rapid, not constant, and are less pronounced on fixation. The irides react promptly to light and convergence. The pupils are equal. No ophthalmoscopic changes are present. A double advancement after the method of Worth was done at the same time on the external recti. Ten days later, as there was a residual squint of 8° (perimetric), a tenotomy of the internal rectus of the left eye was done. For some time there was a most annoying diplopia. The image could not be made to fuse by any combination of prisms. About one month later the diplopia was no longer annoying, and is now little regarded. There is at present a R. H. of 9° (prismatic). There is orthophoria for the lateral muscles.

Duane divides these cases into two groups—those occurring in infants and those in later life. In the first group it is met with in spasmus nutans, and with unilateral opacities in the media. In the

second group, it is met with in unilateral amblyopia and squint, unilateral astigmatism of high degree, and in diseases of the nervous system. He considers that these cases do not differ materially in causation from the bilateral type. The primary cause is probably the same—perverted action of the centers governing co-ordination.

Verhoeff's explanation of a case with squint is that "at first there is a cortical lesion, probably congenital in origin, that tends to produce nystagmus in both eyes. This is associated with, although independent of, an absence of the function of binocular single vision, which leads to the development of squint. Owing to one eye being now used for fixation, its tendency toward nystagmus is fully compensated for. On the other hand, the squinting eye never being used for fixation, its tendency toward nystagmus is allowed to become manifest.

From a consideration of the frequent *coexistence of nystagmus and squint,* of their alternate appearance in some cases, and their association with prolonged convergence, Fromaget and Henry (*Ann. d'Oculistique,* Vol. 147, May, 1912) conclude that in certain circumstances nystagmus can supervene on strabismus. The co-ordinating centres for the ocular movements are apt to be upset more readily in some people than in others, and some cause like ametropia or anisometropia, may induce squint in some cases and not in others. It would seem that the "tendency for fusion" of images which to some extent prevents squint from manifesting itself may analogously hinder the production of nystagmus. Bilateral retinal impressions are necessary. As an illustration of this condition, they report the case of a young man, with a right amblyopic squinting eye, in whom nystagmus appeared in monocular vision, on convergence and lateral movements. This was accompanied by a sort of pupillary instability, analogous to hippus. A rod interposed between his eyes and the printed page caused the nystagmus to appear, from the cutting off of the image of one eye.

Vestibular nystagmus. Recent studies in nystagmus by otologists, and efforts on the part of oculists to utilize the eye movements as an aid in the diagnosis of the location of nerve lesions, prompted Bartels (*Klin. Monatsbl. f. Augenh.,* August, 1912) to review the recent work in this direction. He mentions briefly the earliest work by Purkinje and others, the investigations of Jansen and Urbantschitsch, as well as the most recent activity of Bárány.

It was Bárány who discovered that when the external auditory canal of the *normal* subject is irrigated with hot water (110°-120° F.), a rotary nystagmus is developed toward the side of the irrigated ear; if the ear is irrigated with cold water, a rotary nystagmus is developed

away from the irrigated side. There is no nystagmus if the labyrinth is diseased. This experiment is also called the *caloric test.*

Sydney Scott *(Ophthal. Review,* p. 155, May, 1914), discussing the otological aspects of the disease, believes that the association of certain forms of nystagmus with labyrinthine stimuli justified the use of the term *labryinthine nystagmus.* This was nearly always rhythmic, having alternate slow and fast components, and it was the secondary or rapid component which served to designate the type. Rhythmic nystagmus could be produced in the healthy person by applying certain excessive stimuli to the semicircular canals: (1) by rapid rotation of the person, (2) by irrigation of the ear for a few minutes with hot or cold water, (3) passing a galvanic current through the head, usually 5 to 10 ma. The nystagmus was then a normal expression of an excessive stimulation of the vestibular nerve. The same could be set up in patients the subject, or who had been the subjects of middle ear disease. In 1910 he formulated the law "the deviation of the head and eyes is in the same direction as the current in the endolymph, and the nystagmus is in the opposite direction." In some cases in which one labyrinth was defunct, spontaneous nystagmus could be arrested by digital compression on the carotid sheath of the normal side.

He had met with twenty-three examples of the "fistel symptom," and in nearly every case he had been able to verify the existence of a labyrinthine fistula, though many cases of fistula occurred without the "fistel symptom" being produced. As regards spontaneous labyrinthine nystagmus, it resembled induced nystagmus in kind and degree, being always symmetrical and generally unilateral. The less acute forms were sometimes seen in cases of acute or chronic otitis media. Spontaneous rhythmic rotary nystagmus to one side was also met with when the opposite labyrinth had become functionless, and disappeared again when both became destroyed. It was possible to measure the strength of the stimulus required to produce nystagmus, for sometimes it was easier to be obtained on one side than the other.

Of the three clinical tests for *vestibular nystagmus:* the fistula test, turning, and the caloric test, Fletcher (*Ill. Med. Jour.*, Sept., 1913) considers the caloric test the most constantly useful. Turning must always be used in case of dry perforations, as irrigation is not to be thought of on account of the danger of causing acute suppuration. The caloric test may be made with clean air, warm or cold, or any other cleanly method which may be devised to change the temperature of the labyrinth wall, except the use of fluids.

Treatment of nystagmus (excluding the occupational type) is rarely effective, although isolated cases have been cured by removal of a con-

genital cataract, by tenotomy or advancement causing relief of a squint, by exercises with a stereoscope and in reading with the aid of perforated diaphragm, by exercise in fixation in various positions of the gaze, and by exercises with rotating prisms (Fuchs). In some patients with a high degree of refractive error, the nystagmus has disappeared after wearing a full correction, even though in some cases the visual acuity remained far below normal.

Loeser and Cassirer (*Ber. Ophth. Gesell.*, Mar. 19, 1908) have found that horizontal nystagmus upon lateral movements of the eye are arrested by rotation of the head in the same direction, but increased upon rotation of the head in the opposite direction.

Veasey (*Amer. Jour. Med. Sc.*, Feb., 1908) reports a case in a girl of 12 years with concomitant strabismus, of intermittent mixed nystagmus (vertical and rotary) of the squinting eye. Correction of the hyperopic astigmatism with stereoscopic exercises caused material improvement in the squint and the movements. For a comprehensive treatment of the subject of *nystagmus after brain injury*, see end of the section on **Military surgery of the eye.**

Nystagmus adnatus. A form of nystagmus occurring at or before birth. Its existence is doubtful.

Nystagmus, Cheyne-Stokes. A form of nystagmus in which the globe exhibits rhythmic movements similar to those of the chest-walls in Cheyne-Stokes respiration.

Nystagmus, Latent. A form of the disease that does not show itself unless provoked artificially. Fromaget and others have reported such instances, Ernest Thomson (*Ophthalmoscope*, p. 685, Dec., 1916) among them. He says that in his case covering one eye in the act of examination started the nystagmus. In another patient vision with the R.E. was 6/18; of the L.E. 6/18. Convergent squint of the right eye. This boy had slight nystagmus on ordinary observation, but it became very much worse on using the ophthalmoscope. Then the fact emerged that under a cylindrical correction the vision of each eye separately was R. not improved, L. 6/12; yet binocularly vision rose to 6/6. Now, eight months later, the vision unaided is R. 6/12, L. 6/9, but binocularly 6/6 full. By using a cover on one eye it is found that a marked rapid nystagmus with one eye covered changed to a scarcely noticeable movement with both eyes uncovered, with corresponding improvement in vision.

Nystagmus lateralis. Nystagmus in which the oscillations are in the horizontal meridian.

Nystagmus, Miners'. See the major heading **Miners' nystagmus,** p. 7834, Vol. X of this *Encyclopedia.*

Nystagmus mixtus. A combination of nystagmus oscillatorius and nystagmus rotatorius in which the direction of the oscillations is diagonal.

Nystagmus, Myoclonic. See **Myoclonus, Ocular.**

Nystagmus oscillatorius. A vibrating or oscillatory trembling motion of the eyes in a horizontal direction in which the positive and negative oscillations occur around the axis of the first pair of extrinsic muscles of the eyeball.

Nystagmus protractorius. A name given by A. Pichler *(Zeitschr. f. Augenheilk*, 1913, p. 36) to a rhythmic protrusion of both eyeballs in cerebral hemorrhage through action of the trochlearis. See p. 1973, Vol. III of this *Encyclopedia.*

Nystagmus, Pseudo-. This condition is characterized by jerky movements, increased at the end of the ocular excursions. According to Uhthoff it is seen in about 46 per cent. of cases of multiple sclerosis, and is generally present in hereditary ataxia. It has been reported in almost all other diseases of the nervous system, and has been found under otherwise normal conditions. Tyson *(Arch. of Ophthal.*, July, 1908) observed pseudo-nystagmus in a patient nine months after an attack of facial palsy, upon attempts to forcibly close the right eyelids, as well as upon forced movements of the eyes to extreme right or left.

Nystagmus, Rotation. This is properly an otological and not an ophthalmological subject, and as such is best studied in modern works on otology to which the reader is referred. However, it may be said here that in the examination of military aviators for the United States service the Bárány (Jones) chair is employed for the development of vestibular or rotation nystagmus in the following fashion: The candidate in the chair with head tilted backward and eyes closed. Revolve the patient toward his right ten times in exactly 20 seconds. The candidate is stopped suddenly, facing the examiner in a good light, and told to open his eyes and look to the extreme left or right (opposite to turning). The eyes will be seen to be oscillating; the quick component, which is the movement most easily seen, will be in the opposite direction to the turning, namely, to the left. The number of seconds duration will be noted. The test is then repeated, turning him to the left. Nystagmus will now be to the right. In each case it should last about 26 seconds. A variation of 10 seconds either way is allowable. The nystagmus is the result of stimulation of the horizontal and anterior semicircular canal and is therefore rotary right upwards or left upwards. See, also, **Nystagmus.**

Nystagmus rotatorius. ROTARY NYSTAGMUS. A circular or rolling mo-

tion of the eyes around the visual axis. It is, however, not always or not entirely due to alternate action of the third pair of extrinsic eye muscles, for the rotary movements may be of the purest kind or they may be united with a lateral or diagonal movement. See **Nystagmus.**

Nystagmus, Vertical. Nystagmus in which the oscillations are in the vertical meridian.

Nystagmus, Vestibular. See **Nystagmus.**

Nystagmus, Voluntary. Ch. Lafon and M. Bonnet *(Recueil d'Ophtalmologie,* Oct., 1909) describe a method by which voluntary nystagmus can be provoked, as evidenced by one of their companions. In order to obtain the greatest degree of oscillation, an object is placed at 10 centimetres distance from the eyes in the median line a little below the horizontal; the object is then strongly fixed while the lids are opened as far as possible. A forced contraction of the external ocular muscles is then made including the occipito-frontalis, when a slight effort of convergence immediately sets the eyes in motion. The oscillations are 3 mm. in amplitude, and have a rhythm of 4 to 5 per second; if the fixed object is removed the oscillations diminish to 1 mm. amplitude, with not more than 2 per second in rhythm; the nystagmus is always horizontal, identical in the two eyes, and the displacements are equal and synchronous; the movements are no longer possible when one eye is covered.

Following the nystagmus no abnormal sensation is experienced beyond a feeling of dull aching at the back of the eyes, and a slight diminution in visual acuity.

Weekers (*Archives d'Ophtalmologie*, Vol. XXXII, No. 2, February, 1912) also describes a case of this rare condition in a young man, 20 years old. He had first caused this "dancing of the eyes" at the age of 7 or 8, and had since provoked it at will, whenever he wished to satisfy himself that he was still able to do it. The movements could be started and stopped at will, whenever he was invited to provoke them. The movements were horizontal, sharp, and rapid, twenty to thirty in ten seconds. During the nystagmus there was marked contraction of the pupil, the pupil assuming a markedly oval shape, with the long axis vertical. The rapidity of the movements precluded the determination of a possible hippus. The moment the movements ceased the pupil again became round. Slight spasmodic contractions of the lids were also noted. In order to start the nystagmus the patient concentrated his mind on his eyes; this he could not do over a long time without causing himself great fatigue. During the nystagmus there is no deviation of the eyes. The eyes are generally in the primary position, but nystagmus is possible in all positions except the extremes. It can also

be produced when the eyes are closed. During the nystagmus the vision is lowered, objects appear deformed. After a few minutes of nystagmus the patient experiences vertigo, from which, however, he quickly recovers. This patient has never had involuntary nystagmus; his vision is normal, and he is an emmetrope. There is no strabismus, no insufficiency, nor muscular paresis. The amplitude of movements is normal, and there is no diplopia, not even during the nystagmus. Family history and general health excellent.

Weekers does not consider voluntary nystagmus an example of voluntary inhibition of the cerebral centers, but as a manifestation of the nervous excitation of the supranuclear centers for the eye movements.

Nyxis. Puncture, or paracentesis.

O

O-. An abbreviation, for ortho-.

O. This, the fifteenth letter of our alphabet, is the only one that cannot be traced to the Egyptian hieroglyphics. It is believed to have been an ideographic picture invented by the Semites to express a sound only found in Semitic languages. This supposition is supported by the correspondence of its semitic name, "*ayin,*" which means an "eye," with its oldest form ⊂⊃, which may be regarded as the picture of an eye.

The symbol for oxygen; an abbreviation for *oculus,* eye; *octarius,* pint.

Obconic. OBCONICAL. Conical inversely, i. e., with the apex downward.

Obdeltoid. Triangular, with the apex downward.

Obduce. OBDUCT. To draw over.

Oberer gerade Augenmuskel. (G.) The superior rectus muscle of the eye.

Oberer schiefe Augenmuskel. (G.) The superior oblique muscle of the eye.

Oberes Augenbraunenloch. (G.) Supraorbital foramen.

Obfuscation. Obscure sight.

Object-blindness. See **Visual aphasia**; also, **Neurology of the eye.**

Object-finder. A device used in connection with the mechanical stage to mark position in the field of view of a microscope.

Object-glass. That lens, or combination of lenses by which the image-forming rays are first received in any optical instrument.

Objectif à grand angle. (F.) Wide-angle lens.

Objective. A lens or combination of lenses in an optical instrument which is next the object and serves to form a real image of it. With the microscope and telescope this real image is then observed with an ocular.

Objective, Dry. An objective in which the space between the front lens and the object is filled with air.

Objective, Homogeneous immersion. An objective in which the immersion fluid has the same refractive index as crown glass; frequently designated as oil-immersion objective, since thickened cedar-oil is the most common homogeneous immersion fluid.

Objective, Immersion. A microscopic objective in which the space between the front lens and the object or the cover-glass is filled with some liquid.

Objective magnifying power. See **Magnifying power.**

Objective symptoms. Those observed by the diagnoser.

Object-line. In *optics,* a straight line situated in the object-space and in an infinitely extended plane in any meridian containing the optical axis of a lens-system. See also **Collinear space-systems.**—(C. F. P.)

Object-plane. In *optics,* the plane perpendicular to the axis in which are located the constituent points of the object placed in front of a lens-system.—(C. F. P.)

Object-point. In *optics,* a point in the plane of the object from whence are emitted the effective ray-bundles incident to a lens-system.—(C. F. P.)

Object-rays. In *optics,* the effective rays emitted from each point of the object placed in front of a lens system.—(C. F. P.)

Object-space. In *optics,* the extent of space traversed by the effective rays (q. v.) emitted from each point of the object placed in front of an optical system. See also **Collinear space-systems.**—(C. F. P.)

Object test card. Illiterate test chart. See p. 4653, Vol. VI, of this *Encyclopedia.*

Oblate. Flattened at the poles.

Obliquation. A turning to one side.

Oblique astigmatism. Until 1887 no attempt had been made by any writer to draw any distinction between oblique astigmatism and astigmatism with its two principal meridians vertical and horizontal. It seems not to have been observed earlier that persons with oblique astigmatism had greater cause for suffering than those whose astigmatism was non-oblique. At the meeting of the American Medical Association of that year, in Chicago, Savage read a paper, in the Section of Ophthalmology, entitled "The Function of the Oblique Muscles in Certain Cases of Astigmatism." This was published in the *Jour. of the A. M. A.*, Vol. 9 (1887), page 589. He claimed that there was some function called into requisition in such cases, that was not exercised in non-oblique astigmatism. His study led him to conclude that the additional work in these cases was done by the oblique muscles. At that time, not knowing the true nature of oblique astigmatism, he erroneously charged that this condition, when uncorrected, called into action the superior oblique of one eye and the inferior oblique of the other. He claimed that this right or left torsioning of the eyes improved vision by bringing one or both oblique meridians to, or nearer

to, the vertical. He then knew nothing of the distorsioning of retinal images in oblique astimgatism; nor had he correctly observed that oblique astigmatics, whose meridians of greater curvature were parallel, did not suffer more than those whose principal meridians were non-oblique, nor did they have greater trouble in wearing correcting cylinders. He only knew that oblique astigmatism, broadly speaking, was more serious than non-oblique astigmatism, and that cases of the former class accepted correcting cylinders with more or less difficulty, while those of the latter class experienced no trouble in wearing the correcting cylinders. He charged the non-symmetric action of the obliques to the then supposed fact that the oblique muscles must always keep the vertical axes of the eyes parallel with each other. In the light of later knowledge this is the true law governing the obliques of all non-astigmatic eyes, and of astigmatic eyes whose principal meridians are parallel. Necessary variations from this law will be set forth in a later paragraph.

A year later (in 1888) H. Culbertson presented a paper before the Section of Ophthalmology at the Cincinnati meeting of the A. M. A., entitled "Binocular Astigmatism," in which he described the changed appearance of objects as seen by some astigmatics when beginning to wear their correcting cylinders. In this paper *(Jour. A. M. A.*, Vol. XI, p. 622, 1888) he presented a few such cases, all of whom had non-parallel oblique astigmatism, except one (No. 7). In none of these cases was there a change in the appearance of an object when viewed with either eye alone. The change came in binocular vision, hence he called the error "binocular astigmatism." The changed appearance as shown by his reported cases was in one end of a rectangular card appearing wider than the other end. He corrected the shape by revolving the cylinder on the side corresponding to the wider end in a definite direction through such an arc as was necessary, in one instance as much as 30°. Usually he left the revolved cylinder permanently in its new place; but in one case (No. 5) he reported that the abnormal, or misshaped, appearance of the card disappeared at the end of one week, the axis of each cylinder being left in the position found in the monocular test. This experience should have repeated itself in all of his cases. Culbertson's theory as to the cause of the condition termed by him "binocular astigmatism," later called "metamorphopsia" by Lippincott, and still later "distorted retinal images" by Savage, can be best given in his own words:

"If a perpendicular be raised anteriorly and horizontally midway between the eyes, from a base-line intersecting each fovea centralis; then, in testing each astigmatic eye separately, the axis of vision will,

in vision remotum, be parallel to said perpendicular. If the ocular muscles are normally balanced in action, the plane which cuts the visual axis in the cornea will be vertical. In the normal eye, its fellow being covered, during vision proximum, still the visual axis may be parallel to our perpendicular, and hence the angle of the axis of the cylindrical glass may often be the same in remote and near vision, when each eye is tested singly. In binocular vision, when astigmatism is present, the distance is so great in remote vision, that the visual axes are each parallel to our perpendicular and to each other, and when the ocular muscles are harmonious in action, types and astigmatic bars are seen in normal form. So will vision be perfect near at hand, in astigmatism, provided this due balance is maintained in these muscles.''

It would appear that Culbertson had no conception of the distortion of retinal images, and that he charged the changed appearance of objects to imbalance of the ocular muscles, mentioning by name ''the interni, inferior oblique and superior and inferior recti.'' In the paragraph immediately following the one from which the above quotation has been taken he says: ''If these muscles do this there can be no binocular astigmatism.'' It is clear that what he meant to say in the sentence just quoted is this: If the ocular muscles in distant and near vision keep the vertical axes of the eyes parallel with the median plane of the head there can be no binocular astigmatism, hence in binocular vision there would be no necessity for changing the axis of a correcting cylinder from the position found in the monocular test.

In the construction of his planes, as quoted above, Culbertson is neither clear nor correct. His base line he has made to pass through the two foveas, when it should have connected the two centers of rotation. One of his planes is the median plane of the head, bisecting the true base-line. His two other planes are the planes of the vertical corneo-retinal meridian in which lie the vertical axes of the eyes. When he speaks of the well balanced ocular muscles paralleling the visual axes with the median plane of the head, he means the paralleling of the vertical axes of the eyes with the median plane, and with each other. He charged the metamorphopsia to muscle imbalance, or heterophoria, and corrected the misshape by revolving the axis of one or both cylinders, thus allowing, as he thought, but in reality compelling, a loss of parallelism between the vertical axis of the eye with the median plane of the head. He knew nothing of the distortion of the retinal images by the astigmatism and the compensating cyclotropia it demanded, in binocular vision; nor in this was he a whit behind any one else. If he had been content to leave the axis of each cylinder in

the position found in the monocular test, he would have been rewarded later in finding rectangles assuming their real shape, his cylinders having corrected the astigmatism and, at the same time, cured the compensating cyclotropia. Farther on the real nature of Culbertson's binocular astigmatism will be shown.

Lippincott was aroused by the Culbertson paper to resume a study which he had dropped years before, because "the matter did not seem to be of such engrossing importance as to develop an attack *cacoethes scribendi*." In his publication in the *Archives of Ophthalmology*, Vol. 18, p. 18, 1889, Lippincott says many interesting things. He pronounces Culbertson's hypothesis unscientific and his treatment improper, and it was this conviction that prompted him to write his paper. The title of his paper is "Binocular Metamorphopsia Produced by Correcting Glasses." The following is one important paragraph in the early part of his paper: "The literature of the subject is, so far as my opportunities for investigation have gone, conspicuous by its absence. Donders, Stellwag, and other systematic writers speak of the effect of glasses in changing the form of retinal images, and Knapp, in pointing out the features of irregular astigmatism, mentions, *inter alia*, metamorphopsia—straight lines appearing curved; etc. But it is evident that monocular phenomena are referred to, and I can find no allusion to an apparent change in the forms of objects produced by correcting refractive aberrations, this change necessitating, as an essential condition, the existence of binocular vision. How necessary the latter is will, I think, appear in the course of this paper."

In the last sentence quoted above the word "latter" must refer to metamorphopsia occurring only in binocular vision. To Culbertson then must belong the credit of having written the first words on this kind of metomorphopsia, even though his conception of the cause and correction was erroneous. Others must have observed these phenomena, but, having no explanation for them, and knowing, from observation, that they would vanish, had not written about them.

In the first part of another paragraph Lippincott correctly says: "When both eyes require cylinders of the same degree the axes must be unparallel," meaning, in order that there may be metamorphopsia in binocular vision. In another sentence in the same paragraph he makes the following incorrect statement: "when the glasses correspond in strength and the axes in position (actual isometropia) any obliquity of the latter (the axes of the cylinders) is compensated for by turning the head, and the observed objects are thus prevented from assuming an unnatural appearance." The fact is that, in such eyes, there can be no binocular metamorphopsia whatever may be the pose of the head.

"Homer noded" at the time he made the above record, for it could not have been based on either reason or observation.

For the production of metamorphopsia both Culbertson and Lippincott are in agreement that binocular vision is essential. Culbertson wrote of the metamorphopsia in which the upper and lower borders of a rectangle were wanting in parallelism, with right and left borders necessarily of unequal length. In these cases he had also observed that the floor would be slanting towards the one side or the other. In his cases Nos. 1 and 2 he recorded that the sphere or cylinder, one or both, for one eye was stronger than the similar part or parts of the lens for the other eye. In his cases Nos. 3, 4 and 5 the two eyes required lenses of the same power but the axes were unparallel. There was metamorphopsia but he does not give the kind. In these the upper and lower borders of the rectangle must have been unequal in length but parallel while the ends must have been wanting in parallelism. In like manner his remaining cases might be analyzed. It is certain that there are three forms of binocular astigmatism or binocular metamorphopsia: (1) that in which the upper and lower borders of a rectangle are parallel, with the ends diverging or converging above; (2) that in which the ends of a rectangle are parallel, with the upper and lower borders converging at the right or left; (3) that in which the above two kinds of metamorphopsia are combined—the right and left borders, and the upper and lower borders of the rectangle being of unequal length, the opposite borders being, therefore, unparallel. None of these kinds of metamorphopsia can exist except in cases requiring lenses of unequal strength and with axes of cylinders either diverging or converging above. Each eye alone is incapable of causing metamorphopsia whatever may be the nature of the lens, if correctly adjusted. In no case of metamorphopsia should there be permanent shifting of the axis of a cylinder as taught by Culbertson.

Contrary to the teaching of Culbertson "binocular astigmatism" manifests itself in both far and near binocular tests. Lippincott divides cases of binocular metamorphopsia into two groups only, as follows: "(1) Those characterized chiefly by an alteration in the relative dimensions of the top and bottom of the object (rectangle)—unparallelism of the sides. (2) Those characterized chiefly by an alteration in the relative dimensions of the two sides—unparallelism of the top and bottom."

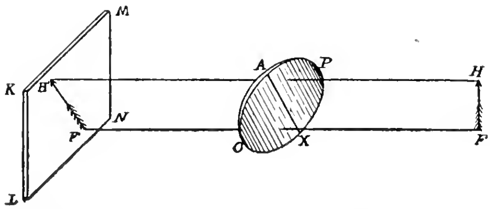
The cases belonging to Lippincott's group 2 are not necessarily oblique astigmatics at all, hence they need not be further studied in this connection. Some of Culbertson's cases have been shown to belong to this group.

In the study of cases belonging to group 1, it is well to quote freely from Lippincott's paper as follows: "Group I—Top (of rectangle) wider or narrower than bottom. (1) Suppose A., who rejoiced in binocular single vision, requires, and is furnished with, R.E. + 1.D, L.E. + 1.25 c. axis 60°. On looking at a perfectly rectangular book, held upright, at ordinary reading distance, the right side of the book looks natural and perpendicular, whereas the left side appears to slope upward and to the right, so that the top of the book seems to him narrower than the bottom. (2) Suppose the R.E. fitted with + 1.D and the L.E. with + 1.25 c. axis 105°, the right side of the book is normal, while the left side slopes upward and to the left, making the top look wider than the bottom. (3) R.E. fitted with — 1.D, L.E. with — 1.25 c. axis 60°, while the right side of the book remains natural, the left side slopes upward and to the left, and the book is wider at the top. (4) R.E. — 1.D and L.E. — 1.25 c. axis 105°; the left side now slopes upward and to the right, and the book is narrower at the top than at the bottom. (5) If A be fitted with R.E. + 1.25 c. axis 100°, L.E. + 1.25 c. axis 60°, the left side of the book will appear to slope upward and to the right, while the right side will slope upward and to the left, though not so much as the left side. Hence the book will appear narrower at the top than at the bottom, the loss in width being sustained mainly by the left side. (6) With the R.E. fitted with + 1.25 c. 80°, and L.E. with + 1.25 c. 105°, the book will appear wider at the top than at the bottom the accession in width pertaining chiefly to the left side. To avoid repetition, the condition of the last two cases will be reversed by substituting concave for convex cylinders. Finally, the form-changes described in the foregoing hypothetical cases can be observed by emmetropes before whose eyes cylinders are placed under the conditions stated above."

The phenomena described in the above quotation are universal. and they could not have been more clearly set forth. Lippincott failed, however, to draw the distinction between corrected oblique astigmatism and artificial astigmatism. In the natural oblique astigmatism, uncorrected, the patient does not complain of metamorphopsia though it has always been present; but the moment the correction is given a new kind of metamorphopsia appears and is more or less readily observed by the patient, and is always annoying so long as it exists. It is this new metamorphopsia that is described in connection with his six hypothetical cases—such cases are real and numerous in the practice of every ophthalmologist.

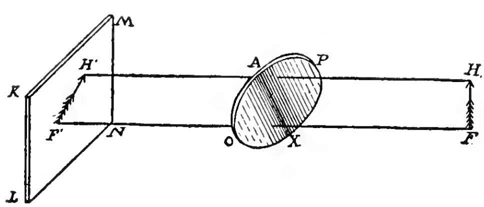
In the artificial oblique astigmatism mentioned in the last sentence quoted above, the metamorphopsia is caused by the astigmatism and not

by the correction as in the six cases recorded. Correct the artificial astigmatism produced by — cyls. axes diverging, with + cyls. of the same strength, axes superimposed, and the metamorphopsia disappears at once. The image changes in the artificial oblique astigmatism of equal degree must be the same as in natural oblique astigmatism. In the one metamorphopsia shows itself, in the other, uncorrected, it does not appear; correct the artificial and the metamorphopsia disappears,



First Figure Showing the Form-changes in Artificial Oblique Astigmatism. (Lippincott.)

but correct the natural and it not only appears but is annoying, and continues for a varying length of time to finally disappear. When the rectangle that was wider above through correcting cylinders, plus or minus, has become a rectangle, then removing the cylinders will make the rectangle appear wider below; just as it would appear in artificial astigmatism of the same kind. Likewise the lowering of the correcting cylinders will immediately restore the rectangle to proper shape, as does the cylinders correcting the artificial astigmatism. These points



Second Figure Showing the Form-changes in Artificial Oblique Astigmatism. (Lippincott.)

were not observed by Lippincott, or if observed were not published in his paper.

To explain the form-changes observed by artificial oblique astigmatics Lippincott introduced two interesting and instructive figures which are here reproduced.

Both figures can be best studied by using Lippincott's own words. "In Fig. 1 PAOX may be taken to represent a convex cylinder with its edge turned towards the observer, and with its axis, AX, oblique. It

is scarcely necessary to add that each half, AOX and APX, may be regarded as a prism with its base at AX. KLNM is a surface parallel to the plane of the lens. It is clear that a ray of light starting from the head of the vertical arrow, H, will fall to the distal (from the observer) side the axis, and will thus be deflected by the prism APX toward the proximal side, KL, of the surface KLNM, to the point H′. Similarly a ray starting from F will come within the influence of the prism AOX, and will be deflected towards the distal side, MN, to the point F′. Again, if in the second figure, PAOX be a simple concave cylinder, thus consisting virtually of two prisms whose bases lie towards P and O, it is plain that the ray HH′ will be deflected by passing through the prism APX towards the distal side MN, while the ray FF′ will be refracted towards KL. Hence the image on the surface KLMN is inclined instead of vertical. It may be added that the deflection of the rays will be greater in proportion as the cylinder is stronger, and in proportion as the axis approximates the position midway between the vertical and the horizontal.''

It would have been both elucidating and interesting if Lippincott had introduced a third figure representing the same arrow HF and the same surface KLNM, placing between them the two oblique cylinders, the + cylinder of Fig. 1 and the — cylinder of the second figure not far removed from each other and with their axes in a common plane. The rays from H and F in passing through the + cylinder would be deflected as shown in Fig. 1 but these rays on striking the — cylinder would be deflected as shown in Fig. 2. The first deflection would be counteracted by the second deflection and the image or shadow H′F′ would not be inclined either to the left or to the right, but would be vertical. The two cylinders neutralizing each other would be equivalent to a plane glass which being parallel with the arrow HF and the surface KLNM could not deflect the rays HH′ and FF′.

Still another figure might have been introduced by Lippincott which could have been marked No. 4. In this figure he could have placed between the arrow HF and the surface KLNM the same + cylinder shown in Fig. 1 and behind that another + cylinder of the same power, the axis of the latter being at right angles to the axis of the former. The double deflection would cause the image or shadow H′F′ to be vertical, and in the same plane with HF.

Lippincott passed immediately from his study of figure two to a study of natural oblique astigmatism with its image-changes and corresponding form-changes. The following is the language he uses: ''Let us suppose KLNM in Fig. 2 to represent the retina of an emmetropic left eye, before which is placed the — cylinder PAOX. In the

retinal image the arrow head will point downward and to the left, and, by the well known law, the mental image will be projected in the opposite direction, so that the arrow will appear to be inclined upward and to the right.

"Now, we may, for our present purpose, consider an eye affected with simple HAS as equivalent to an emmetropic eye with a concave cylinder, such as PAOX (Fig. 2) placed in front of it. In like manner we may regard an eye affected with MAS as equivalent to an emmetropic eye with a convex cylinder, such as PAOX (Fig. 1) in front of it. Hence in a case of astigmatism, axis oblique, the image of a vertical line occupies, not a vertical, but an oblique position on the retina; and hence, in such a case, there ought to be an apparent inclination of one or both sides, as the case may be, of a square."

The above language clearly entitles Lippincott to the credit of having both discovered and first published the obliquity of retinal images in oblique astigmatism. In the last sentence quoted above he might have substituted for his language "There ought to be an apparent inclination of one or both sides, as the case may be, of a square," these words: "There must be an inclination of one or both sides, as the case may be, of a square, of which patients seem not to be conscious." Such patients become conscious of the distorted rectangle, caused by the distorted retinal images, only after they have become accustomed to their correcting cylinders. Take Lippincott's case No. 6 in which the meridians of greatest curvature diverged above. Through the correcting cylinders, for a few days, this patient saw a rectangle changed to a trapezoid with greater width at the bottom. Later it became a perfect rectangle through the lenses. Now the rectangle will be seen as a trapezoid, longer side above, whenever the glasses are raised. Raising the glasses of an oblique astigmatic will make him see a rectangle, just as an emmetrope will see the figure when given an oblique artificial astigmatism of the same kind. The explanation of the nonobservance of metamorphopsia by uncorrected astigmatics will be given further on.

Before pursuing further the study of apparent changes in objects, it will be well to enunciate some laws governing retinal images. (1) In emmetropia, hyperopia and myopia the image of a line, held in any position is always in a plane with the line itself. (2) In astigmatism, simple, compound or mixed the image of a line can be in the plane with the line itself only when the line is in the plane, or parallel with the plane, of one of the principal meridians. The images of all other lines are rotated towards the plane of the meridian of greatest curvature of the cornea. (3) The extent of the rotation of the image in any given case is greatest when the line is in a plane equally distant (45′)

from the planes of the two principal meridians. (4) The greater the quantity of the astigmatism, the more will the image of a line be rotated towards the plane of the meridian of greatest curvature.

The image of a rectangle is always rectangular on the retina of a non-astigmatic eye, regardless of the position in which the rectangle may be held. The image of a rectangle is itself rectangular only when the figure is so held that its two sides shall be parallel with the plane of one principal meridian and its two ends shall be parallel with the plane of the other principal meridian. The rectangle held in any other relationship to the astigmatic eye will throw a non-rectangular parallelogram image on the retina.

The law of corresponding retinal points—the supreme law of binocular single vision—has no existence in monocular vision. Since no other law, physical or mental, can suspend, or in any way modify, the law of visible direction, it is clear that, in monocular vision, the object must always appear to have the shape of its retinal image. It can appear in its real shape only when seen by a nonastigmatic eye, or an astigmatic eye looking through its correcting cylinder. With such an eye a square will be a square whatever may be the position in which it is held, its plane being parallel with the transverse plane of the head. An uncorrected astigmatic eye can not see a square as a square when held in any position, but when it is so held that its two opposite sides are parallel with one of the principal meridians it is seen as a rectangular parallelogram. In any other position it is seen as a nonrectangular parallelogram. In either case it assumes the shape of the retinal image, in strict obedience to the law of visible direction. In monocular vision with an astigmatic eye, whether the astigmatism be natural or artificial, the image changes will take place when the square is being revolved, and the square will appear to take the shape of the image. In the revolving of the figure the natural astigmatic of 3D, using only one eye, will see the changes in shape taking place as readily as will the emmetrope who has been given 3D of artificial astigmatism.

The law of visible direction is never interfered with in binocular vision when the eyes are emmetropic, hyperopic or myopic, nor is this law ever interfered with in the binocular vision of astigmatics whose meridians of greatest curvature are parallel. In binocular, as in monocular, vision a square will always be seen as a square by the non-astigmatic. The astigmatic, whose meridians of greatest curvature are vertical, will see a square as a rectangular figure only when it is so held that its sides are vertical and horizontal. In any other relationship the square will appear, in binocular, as in nonocular, vision, as a non-rectangular parallelogram. In parallel oblique astigmatism the image

changes, and the apparent object-changes, in binocular vision will be precisely the same as in vertical astigmatism, when the square is held in corresponding relationships to the principal meridians. In either case the images and the objects have the same shape in perfect obedience to the law of visible direction, and this will be true whether the astigmatism be natural or artificial. The law of corresponding retinal points and the law of visible direction work in perfect harmony in parallel astigmatics and in non-astigmatics. After the correction of parallel astigmatism, whether vertical or oblique, the astigmatism being equal in both eyes, there will be no metamorphopsia, for the law of corresponding retinal points and the law of visible direction will continue to work in perfect harmony. A square will be seen as a square at once and always by such artificial emmetropes.

The law of astigmatic refraction, expressed in different words from those already used, compels the image of every line, not in the plane of one of the principal meridians, or parallel with it, to be rotated towards the plane of the meridian of the greatest curvature. If the meridians of the greatest curvature in the two eyes are not symmetric the retinal images must be unlike. In any given position of a rectangle each eye will have its own pecular image. If the meridians of greatest curvature diverge above, a rectangle held vertically will have a non-rectangular retinal image in the right eye inclined down and to the left, while that in the left eye will be of same shape but inclined down and toward the right. With either eye covered the other will have its image and the object precisely of the same shape, that is, the right eye will see the rectangle transformed into a non-rectangular parallelogram inclined down and towards the left, while the left would see the same kind of figure but inclined down and towards the right. In binocular vision the figure would not be a rectangle nor a parallelogram but a trapezoid with the longer side above. Just the reverse of this would occur in an astigmatic with meridians of greatest curvature converging above—with either eye alone the parallelogram would turn down and towards the corresponding side, and in binocular vision the trapezoid would have its longer side below. Rotating the rectangular figure so that its sides would be parallel with the two principal meridians of the right eye, the other eye being covered, the image would become rectangular and the figure would be like it. Holding the figure in the position into which it was rotated for the right eye, this eye being now covered, the want of parallelism of the sides of the figure with the two principal meridians of the left eye will be increased, and the image will be changed the more. As is always true of monocular vision the figure will have the shape of its image—an exaggerated non-

rectangular parallelogram. The figure being held in the same position will be metamorphosed in binocular vision into a trapezoid the longer side above or below, depending on the convergence or divergence of the meridians of greatest curvature above. What has been said about astigmatics, whose meridians of greatest curvature are equally inclined but in opposite directions, is true, but not to the same extent, in all cases of nonparallel oblique astigmatism. This is also true whether this meridian is vertical in one eye but oblique, either in or out, for the other eye, or whether they are both oblique, but unequally so, in opposite directions, or in the same direction. It is also true of

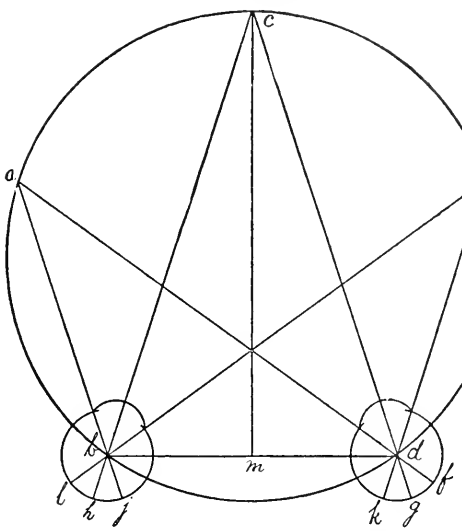


Fig. 3. Isogonal Circle. (Savage.)

unequal astigmatism with the meridians of greatest curvature oblique but parallel.

The appearance of an object—a rectangle—can be the same in binocular vision as in monocular vision, only when the two eyes are non-astigmatic or, if astigmatic, when the meridians of greatest curvature are of the same radius and parallel. Only non-astigmatic eyes can ever see an object as it really is.

Corrected astigmatism is artificial emmetropia, and in both monocular and binocular vision should see an object—a rectangle—as it really is. Astigmatics whose meridians of greatest curvature are parallel, whether vertical or oblique, the astigmatism being equal, or nearly so, in the two eyes, when corrected will immediately and forever see a rectangle, or any other figure, as it really is, in obedience to both the

law of visible direction and the law of corresponding retinal points. All other astigmatics, through correcting lenses, at first have metamorphopsia, in binocular vision only, in obedience to the law of corresponding retinal points and in disobedience to the law of visible direction. The latter law is supreme in monocular vision, but the former is the only supreme law in binocular vision. The law of visible direction determines not only the direction of an object in space, but also the shape of an object, in monocular vision, whether the eye be perfect or imperfect in its refraction. It is this law that compels the shape of the object to be that of its retinal image, which is not in all cases its real or true shape. In the binocular vision of natural emmetropes and in those who are made emmetropic by the correcting of ametropic conditions other than nonparallel and unequal parallel oblique astigmatism, the law of visible direction has full sway, causing objects to assume their proper shapes. For such there is never any binocular metamorphopsia. In those artificial emmetropic cases in which there is binocular metamorphopsia, the law of visible direction has been suspended by that higher and more exacting law of binocular single vision, the law of corresponding retinal points. Since the metamorphopsia can not disappear until these two laws are brought into perfect harmony, it is well to study these laws separately before attempting to show how they can be brought into harmony, and why there has ever been a want of harmony.

LAW OF VISIBLE DIRECTION.

Every line of true direction is a radius of retinal curvature prolonged; therefore, in monocular vision and perfect binocular vision, all lines of direction cross at the center of retinal curvature.

For a full defense of this law as against Helmholtz' axial ray theory of visible direction, the reader is referred to *Ophthalmic Myology,* second edition, chapter 1.

The retinal radius theory makes possible the construction of the true horopter, or isogonal circle represented in Figure 3.

Not only does this law furnish the true circle of binocular single vision, but it makes possible the construction of the true surface of binocular single vision, which is made by revolving the circle around the line b-d, which connects the centers of the two eyes.

On this law has been constructed the muscle indicator, shown in Figure 4, by means of which can be demonstrated every phase of a single ocular muscle or any combination of ocular muscles, normal, abnormal or pathological.

This law is supreme in monocular vision, whatever may be the refrac-

tion of the eye; it is unmodified in the binocular vision of eyes that are emmetropic, myopic, hyperopic, and in astigmatic eyes whose meridians of greatest curvatures are equal and parallel. This law is entirely suspended by the law of corresponding retinal points in the binocular vision of uncorrected astigmatics whose meridians of greatest curvature are wanting in parallelism.

When the law of visible direction and the law of corresponding retinal points are in harmony, the vertical axes of the eyes are always

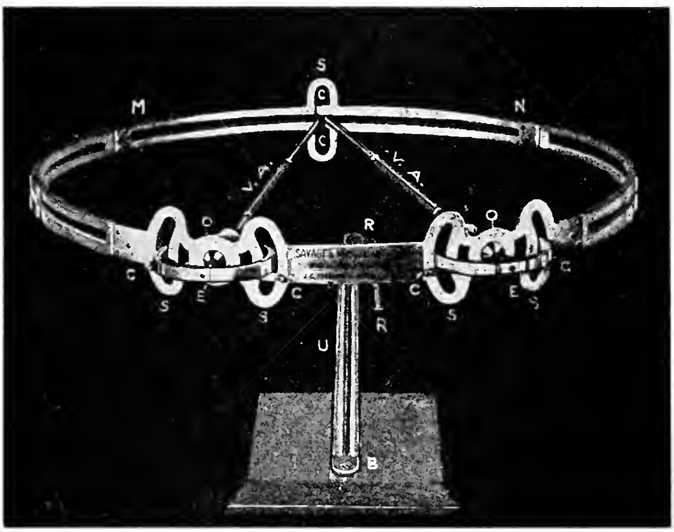


Fig. 4. Muscle Indicator. (Savage.)

parallel with the meridian plane of the head; but when the former law is suspended by the latter, the vertical axes of the eyes are made to diverge from, or converge towards, the median plane of the head. When these laws have been in harmony in the binocular vision of uncorrected ametropes, there can be no metamorphopsia, immediate or remote, when the ametropia has been converted into artificial emmetropia. When these laws have been in conflict in the binocular vision of ametropes, then there will be metamorphopsia immediately following the conversion of the ametropia into artificial emmetropia; but when the old conflict between these two laws ceases, as it must, the cause of the war having been removed by the correcting lenses, then the metamorphopsia disappears forever.

LAW OF CORRESPONDING RETINAL POINTS.

This is the supreme law of binocular single vision, and must be obeyed else one of two results will follow: (1) there will be double vision, as always occurs in paresis or paralysis of one or more ocular muscles; or (2) there will be monocular mental suppression as in most cases of heterotropia beginning in early life. It can have sway only in binocular vision. There is harmony between this law and the law of visible direction in all non-astigmatics and in astigmatics whose meridians of greatest curvature are equal and parallel, whether vertical or oblique. There can be no such harmony in uncorrected non-parallel astigmatism. In natural emmetropia always, and in artificial emmetropia, at once or a little remotely, there is perfect harmony between these laws. An outgrowth of this harmony is correct judgment as to direction and distance of an object, and as to its shape and size. Direction and shape need no other factor; but other factors aid in the function of judgment as to size and distance.

The old teaching concerning corresponding retinal points, if true, would make binocular single vision possible to all people. There are many who have never seen singly with the two eyes and can never be made to thus see. Graefe, who first studied such cases, contented himself by saying that they had antipathy to binocular single vision. When binocular vision is possible, because of the existence of a fundamental condition or principle to be stated presently, then the macula of the one eye corresponds with the macula of the other eye; the horizontal meridian of the one eye will correspond, point to point, with the horizontal meridian of the other eye; the vertical meridian of the one eye will correspond everywhere with the vertical meridian of the other eye. Likewise all parallel oblique meridians will correspond throughout. The upper half of the two retinas will correspond, the two right quadrants with each other and the two left quadrants with each other. Likewise the two lower halves of the retinas will correspond, the two right quadrants with each other and the two left quadrants with each other. The temporal half of one retina will correspond throughout with the nasal half of the other retina.

The fundamental fact of binocular single vision is common brain-cell connection of retinal points that correspond, because of which they do correspond, and without which they can not correspond. Normal retinal-brain connection means binocular single vision whenever muscle adjustment is possible. The macula of the one eye has hundreds of fibres going from it to the brain. A like number of fibres go from the macula of the other eye to the brain. The macula is always bisected by

the plane of the vertical meridian, but this plane does not always divide the retina into its two halves as they are related to the brain, but when it does, all the fibres from the right halves of the two maculas go to the right cuneus, those from the right eye not crossing but those from the left eye crossing in the chiasm, to meet their associates in the right optic tract. In the tract, or further on in the brain substance, these many fibres so relate themselves, after the Creator's design, that they become pairs, one of a pair from a retinal point in the one eye, the other from a retinal point in the other eye, and terminate together in one common brain-cell. Thus all the fibres from the right halves of the two retinas arrange themselves in pairs, each pair to terminate in a brain-cell common to both, and all these brain-cells are grouped in the right cuneus. In like manner the fibres from the left halves of the two retinas arrange themselves in pairs, each pair terminating in a common brain-cell, all of these cells being found in the left cuneus. This fact of common brain-cell connection of corresponding retinal points and parts, makes binocular single vision possible. This easily explains double impressions, yet single sensation.

The agents for properly relating these points are the ocular muscles —the recti and the obliques—under the control of their respective individual motor centers, the fusion centers at the base of the brain. When these muscles, because of congenital imbalance, can not properly relate corresponding retinal points, some form of heterotropia developes, usually in the first, second or third year of life, the companion of the crossing being blindness from mental suppression—mind-blindness, and not eye-blindness.

In the comparatively rare cases of antipathy to binocular single vision, there is not common brain-cell connection, probably one macula as a whole being connected with one cuneus, while the other macula is entirely connected with the other cuneus. One eye or the other is permanently crossed from birth, or they cross alternately, but mental blindness does not occur in either eye. Temporary suppression prevents diplopia, or the eye crosses sufficiently to throw the false object so far away from the true that there is no confusion from the diplopia. Any attempt to fuse the images in such eyes will be a failure, whether the attempt be with prisms or by operations, one or both. Over such eyes the law of corresponding retinal points has no sway, therefore there can never be binocular astigmatism or binocular metamorphopsia, as described by Culbertson and Lippincott.

There is still another view-point from which corresponding retinal points may be studied, that will aid in arriving at a correct understanding of the nature of binocular metamorphopsia. An examination

of Figure 5 will show a retinal line drawn parallel with the horizontal retinal meridian, through a point on the vertical retinal meridian just ten degrees from the fovea; likewise is shown a retinal line that is drawn parallel with the vertical retinal meridian, through a point on the horizontal retinal meridian just ten degrees from the fovea. Since retinal points that correspond in the two eyes bear the same relationship to the macula, and to the horizontal and vertical retinal meridians, it becomes perfectly clear that these lines correspond everywhere, just as do the meridians. The intersection of these parallels and meridians makes a retinal square, one side of which is a part of the vertical meridian and another side is a part of the horizontal meridian, and

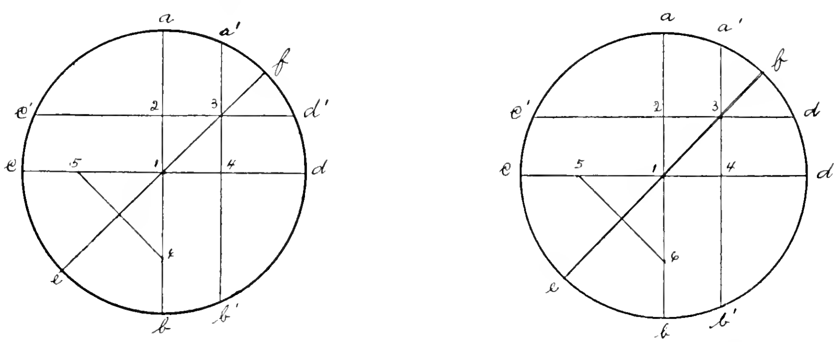


Fig. 5. Diagram Illustrating Binocular Metamorphopsia. (Savage.)

since these two sides are of equal length, the other two sides must be of equal length with them. The diagonal of this square in each eye is retinal meridian 45°. Since three of the corners of the square in one eye certainly correspond with the three corners of the square in the other eye, the fourth corner of the one must correspond with the fourth corner of the other. The three corners (or points) that must correspond are: (1) the foveas; (2) the two points on the horizontal retinal meridians 10° removed from the foveas; (3) the two points on the vertical meridians 10° removed from the foveas. Since the other two corners lie on meridians 45°, equally distant from the two foveas, they must also correspond. If the corners of these retinal squares are corresponding retinal points, the respective sides of the squares must be corresponding retinal lines and the surfaces included must be corresponding retinal surfaces. While in the figure only one retinal square has been constructed for each eye, the whole retinal surface might have been thus divided. By the single squares comprehension is made more easy.

Rectangular figures other than squares might have been constructed,

making the point of intersection on the vertical meridians 10° and that on the horizontal meridians 20°, with the same result as to corresponding retinal lines and surfaces.

Without complicating Figure 5, two oblique lines are drawn in the lower right hand quadrants connecting points on the vertical and horizontal meridians 20° from the foveas. The two areas are precisely of the same shape and size and therefore must everywhere correspond, seeing that the three corners—the two foveas, the two points on the vertical meridians, and the two points on the horizontal meridians—are corresponding retinal points. The two equators are composed of corresponding retinal points, for every point on each equator is 90° from the fovea, and each point is cut by a retinal meridian. Every retinal circle parallel with the equator is, likewise, composed of retinal points

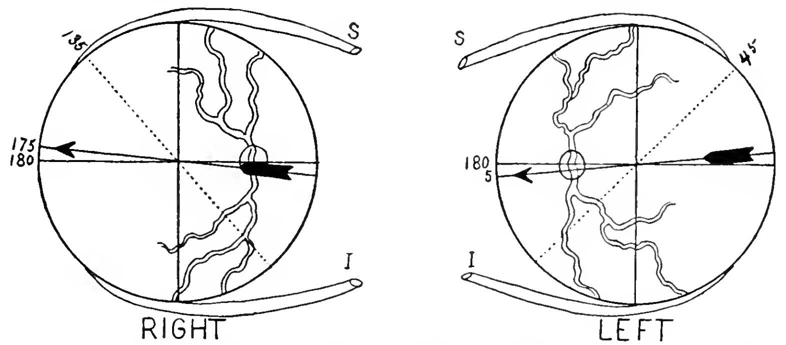


Fig. 6. To Illustrate the Law of Corresponding Retinal Points in Its Relation to Oblique Astigmatism. (Savage.)

that correspond with retinal points on a parallel in the other retina bearing the same relationship to the fovea of its eye. The spaces or zones between any two of these parallels, equally removed from the foveas, are composed of corresponding retinal points.

As already shown, in monocular vision, in obedience to the law of visible direction, any figure will take the shape of its retinal image. The image will have the shape of its object only in a non-astigmatic eye, and such an eye only can see an object as it really is. For convenience a square held in the upright position, with its plane parallel with the plane of the equator of the eye, has been chosen for study. The emmetropic eye will see the square in its real size as well as shape; the hyperopic eye will see the square in its real shape, but reduced in size; the myopic eye will see the square in its real shape but enlarged; the astigmatic eye, with meridian of greatest curvature vertical, having a rectangular parallelogram image, will see the square as a rectangular

parallelogram longer sides right and left; the astigmatic eye, with meridian of greatest curvature oblique, will have a non-rectangular parallelogram image, hence it will see the square as a non-rectangular parallelogram, and leaning. Whatever may be the refraction of a pair of eyes, if it is the same in the two eyes, the object in binocular vision will be shaped as in monocular vision, for the two images will be alike, falling on corresponding retinal parts. The law of visible direction and the law of corresponding retinal points work in perfect harmony in such eyes, and because of this harmony, the vertical axes of the eyes remain parallel with the median plane of the head, as in monocular vision.

If the images of a horizontal line are oblique to the same extent and in the same direction, they fall on corresponding retinal lines, and an

Fig. 7. The Images on the Retina in Oblique Astigmatism. (Savage.)

oblique line is seen in binocular vision, just as in monocular vision. If the images of a horizontal line are oblique but not in the same direction, although to the same extent, they do not fall on corresponding retinal lines, as shown in Figure 6. Unless retinal lines that do correspond are

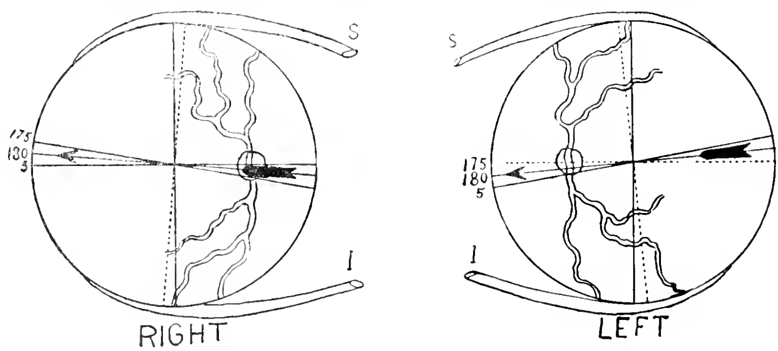


Fig. 8. The Retinal Images in Oblique Astigmatism. (Savage.)

brought under such displaced images, the line will appear double, as shown in Figure 7, in obedience to the law of visible direction, but in disobedience of the supreme law of corresponding retinal points.

When binocular single vision is possible, the law of corresponding retinal points must be obeyed. The servants of this law are the ocular muscles. The muscles brought into action by this law, in the pair of eyes represented in Figure 6, are the two superior obliques. The eyes

in this figure have oblique astigmatism, the dotted lines showing the meridians of greatest curvature diverging above. The image of the arrow in each eye is rotated towards the meridian of greatest curvature, falling on meridian 175° of right retina and on meridian 5° of left retina. These meridians do not correspond. To see the arrow singly with the two eyes the rotation by the superior obliques shown in Figure 8 must occur. In bringing meridians 180° under the oblique images, corresponding retinal lines are impressed, but the vertical axes of the eyes are made to converge toward the meridian plane of the head.

If the arrow had been held vertically before the eyes shown in Figure 6, the image in each eye would have been rotated towards the meridian of greatest curvature, that in the right eye standing at 95°, while that in the left eye would be on meridian 85°. The law of corresponding retinal points would cause the inferior obliques to bring corresponding meridians 90° under the displaced images, so that the arrow might appear as one.

If there had been two arrows, one horizontal and the other vertical, crossing each other in the center, the astigmatic eyes represented in Figure 6 would have had the images in each eye rotated towards the meridian of greatest curvature, hence towards each other. Each eye alone would have seen the two arrows forming an angle of 80°. In the right eye the two images would lie respectively on meridian 175° and meridian 95°. In the left eye the images would be on meridians 5° and 85°. As already shown, if there had been but one arrow and it either horizontal or vertical, the eyes would be rotated by either the two superior or the two inferior obliques, so as to bring corresponding retinal meridians under the displaced images, thus effecting binocular single vision. With the two arrows the fusion of the images of the horizontal arrow, by action of the superior obliques bringing the two horizontal meridians under the displaced images, would cause the displaced images of the vertical arrow to fall on meridians further removed from harmony, viz. the right on meridian 100°, and the left on meridian 80°. The horizontal arrow would be seen single, in obedience to the law of corresponding retinal points; and the vertical arrow would be seen double, as if, but not, in obedience to the law of visible direction. That is, the horizontal arrow would be seen single by the two eyes acting together, while each eye would see its own vertical arrow, the two crossing at an angle of 20°. Or if the inferior obliques had fused the displaced images of the vertical arrow, making it one for the two eyes, each eye would have seen its own horizontal arrow, and the two would have crossed at an angle of 20°. Perfect fusion of the

images of a single arrow, horizontal or vertical, however great their displacement by oblique astigmatic refraction, is possible under the law of corresponding retinal points, but the fusion of the images of both can not be accomplished. Has the mind any preference as to which of the two pairs of images shall be fused? Or why should there be an attempt to fuse either pair of images? Both of these questions will be fully answered in the study of Plate II and III. Visual perceptions and visual judgments are best when the law of corresponding retinal points calls on the direction, or fusion, centers to so rotate the two eyes as to bring corresponding retinal lines under the displaced images of a horizontal, or nearly horizontal, line, whenever a figure, as a rectangle, is composed of both horizontal and vertical lines. Lippincott put it well when he said: "Horizontal measurement is a common ground for the action of the two eyes." Whatever may be the explanation, horizontal lines are always fused, in preference to vertical lines, when the two compose a figure, by both natural and artificial non-parallel oblique astigmatic eyes.

The muscles called into action for effecting such fusion are the obliques, and always in accordance with the following rule: Whenever the meridians of greatest curvature diverge above the two non-rectangular parallelogram images of a rectangular figure are fused by the action of the two superior obliques, the resultant figure being a trapezoid with its longer side above; but whenever the meridians of greatest curvature converge above the two non-rectangular parallelogram images of a rectangular figure are fused by the action of the two inferior obliques, making the rectangle appear as a trapezoid with the longer side below. The purpose of the action of either the superior or inferior obliques being to bring corresponding retinal meridians and parallel retinal lines under the oppositely displaced images of the upper and lower borders of the rectangle.

In the eyes of astigmatics whose meridians of greatest curvature diverge above, the image of a rectangle in each eye is distorted down and towards the opposite side; but in the eyes whose meridians of greatest curvature converge above, the image of a rectangle is distorted down and towards the corresponding side. In either case the distortion of the two images is the same in kind but opposite in direction. This is true whether the astigmatism be simple, compound or mixed.

The fusion of the horizontal sides of the printed page insures the fusion of the printed lines; while the fusion of the vertical sides of the printed page would make the printed lines, as seen by the two eyes, cross each other in great confusion.

The normal action of the obliques, under the guidance of their respective nerve centers, is to compel parallelism of the vertical axes of the eyes with the median plane of the head, in both monocular and binocular vision. This is their only task in non-astigmatics and in astigmatics with the meridians of greatest curvature parallel. In both monocular and binocular vision the obliques thus act in the interest of correct orientation; and in binocular vision this action is in obedience to the law of corresponding retinal points. This work is easily done by the obliques that are well balanced in action—that are free from cyclophoria. The abnormal action of the obliques exists only in the binocular vision of nonparallel oblique astigmatics, and in unequal parallel oblique astigmatics; and the result of this abnormal action of the obliques is either to converge or diverge the vertical axes of the eyes in obedience to the law of corresponding retinal points, but at the expense of correct orientation. Correct orientation is possible only when the law of visible direction is obeyed, that is, when points in space and retinal points are connected by radii of retinal curvature prolonged—when the retinal and spacial meridians lie in the same plane, the retinal and spacial poles being the proximal and distal ends of the visual axis.

By means of Plate I, not only the normal action of the obliques may be studied, but with equal clearness both the law of visible direction and the law of corresponding retinal points are portrayed. The eyes represented in this plate are non-astigmatic, and the object to be studied is a rectangular parallelogram, placed at any fixed distance from the eyes, and directly in front, its plane being parallel with the transverse plane of the head. Rays of light, not shown in the plate, passing from this figure into each of the eyes will be so refracted that an image shall be formed on each retina of precisely the same shape as the object. Since the point of fixation is the center of the rectangle (5), each image is bisected by the plane of the horizontal retinal meridian, and the upper and lower borders are parallel with it and equally distant from it. The plane of the vertical meridian also bisects the image so that the right and left borders of the image are parallel with it and equally distant from it. The same is true of the image in the fellow eye. The upper borders of the two images throughout their length bear the same relationship to their respective foveas and vertical and horizontal retinal meridians, hence they have fallen on corresponding retinal lines. The same is true of the two lower borders, and of the two right and the two left borders, hence the two images have fallen on corresponding retinal areas. In order that these two images may remain on corresponding retinal areas, the obliques must

keep the two vertical axes of the eyes parallel with the median plane of the head.

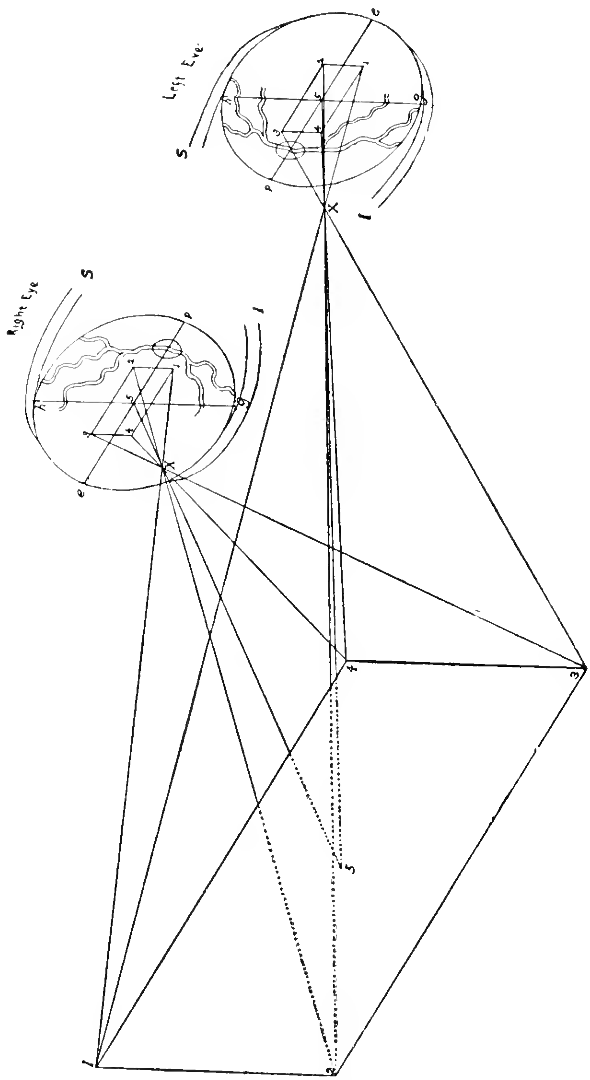


Plate I. Showing the Action of the Oblique Muscles in Relation to Corresponding Retinal Points. (Savage.)

The right eye alone would see the object of the same shape as its image, which will be its real shape, since the image has not been distorted. The line going from the center of the image to the center of

the object is the visual axis. The lines going from the four corners of the image cross the visual axis at x and extend to the corresponding corners of the object, in perfect obedience to the law of visible direction. The visual lines from the image in the left eye will all cross at x, to go from thence to the corresponding points of the object. The figure seen by the left eye is of the same shape as its image and is, in every instance, the same figure as seen by the right eye. In binocular vision the figure has the same shape and size as seen by each eye singly, in perfect obedience to both the law of corresponding retinal points and the law of visible direction. Since the law of corresponding retinal points has not interfered in the slightest with the law of visible direction, orientation in binocular vision is as prefect as in monocular vision.

The eyes in Plate I can be made to represent astigmatic eyes whose principal meridians are vertical and horizontal. In shape the images would be a perfect reproduction of the object, but the image lines corresponding with the meridians of greatest curvature would be elongated, and with this image changed, the corresponding sides of the rectangle would appear elongated, in obedience to the law of visible direction. The two images would fall on corresponding retinal areas, and the object in all of its parts would be seen as one with the two eyes. Under these image conditions the obliques would have to perform only their normal function, the keeping of the vertical axes of the two eyes parallel with the median plane of the head, thus insuring correct orientation in binocular vision as in monocular vision.

Again the eyes in Plate I could be made to represent parallel oblique astigmatism, the two meridians of greatest curvature being at 45°, the points of maximum power for the distortion of retinal images. The two images would be just alike, and similarly related everywhere to their respective foveas and vertical and horizontal retinal meridians, hence they would fall on corresponding retinal areas. Each image of the rectangle in the plate would be a non-rectangular parallelogram image, leaning down and to the right (the upper right hand corner of each image would be nearer the horizontal retinal meridian than the upper left hand corner). Each eye would see the rectangular figure of the same shape as the retinal image, hence it would appear to be a non-rectangular parallelogram, leaning down and to the right, when seen with either the right or left eye. In these eyes all the visual lines would cross each other at x, and since the two images cover corresponding retinal areas, the two eyes together would see the same shaped figure as each eye alone had seen it, in obedience to both the law of corresponding retinal points and the law of visible direction. In such eyes the obliques would maintain the parallelism of the vertical axes

of the eyes with the median plane of the head, but orientation would be defective. The object would be seen as one in all of its parts by the two eyes—perfect fusion.

The eyes thus far discussed in connection with Plate I, viz., the emmetropic, the vertical astigmatic and the parallel oblique astigmatic, have demanded of the obliques only the performance of their normal function, the keeping of the vertical axes of the eyes parallel with the median plane of the head, in obedience to both the law of corresponding retinal points and the law of visible direction. It has been shown that only in the emmetropic eye is correct orientation possible. The hyperope sees the rectangle diminished in size; the myope sees the rectangle increased in size, but neither the hyperope nor the myope sees the rectangle distorted. These eyes, when rendered artificially emmetropic, see the rectangle as the emmetropic eye sees it, hence corrective spherical lenses give to hyperopes and myopes the power of perfect orientation. With or without corrective lenses the oblique muscles of such eyes keep the vertical axes of the eyes parallel with the median plane of the head.

Corrective cylinders give to vertical astigmatics retinal images that are as correct in dimensions as in emmetropic eyes, and through the lenses these eyes have perfect orientation, seeing the square at once and always as emmetropic eyes see it. With or without the corrective cylinders, the obliques of these eyes perform their normal function keeping the vertical axes of the eyes parallel with the median plane of the head.

Corrective cylinders give, to parallel oblique astigmatics, retinal images of a rectangle that are as correct in shape and size as are the images in emmetropic eyes. Through the lenses these eyes have perfect orientation, seeing the square at once and always as emmetropic eyes see it. With or without the correcting cylinders the oblique muscles of such eyes perform only their normal function—keeping the vertical axes of the eyes parallel with the median plane of the head.

Plate II, illustrative of nonparallel oblique astigmatism, is much more complicated than Plate I. The original description of this plate as presented to the International Congress of Ophthalmology at Edinburgh, in 1894, and as republished in *Ophthalmic Myology*, second edition, page 452, is reproduced here for the reason that the language then used can not fail to make clear the lesson intended to be taught by the plate.

"In Plate II 'Both eyes have astigmatism of the same kind and quantity. In the right eye the meridian of greatest curvature is at 135° and in the left eye at 45°. If the rectangular figure represented

in Plate I be held in the same position before the eyes represented in Plate II, it would not be seen with one eye alone, nor with both eyes

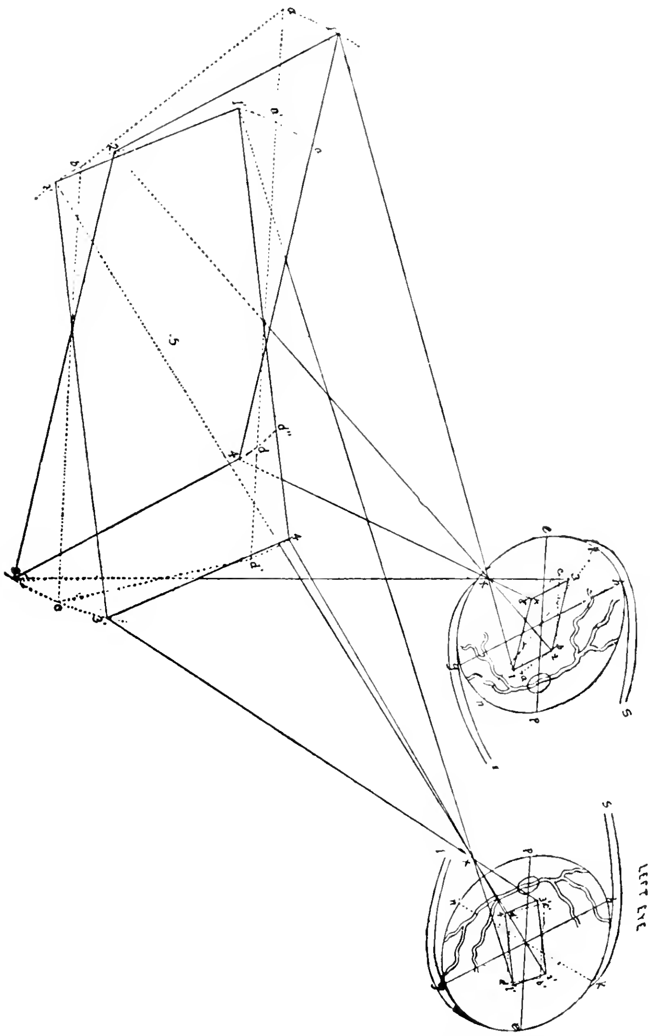


Plate II. Showing the Retinal Images in Non-parallel Oblique Astigmatism. (Savage.)

together, as a rectangle. The rectangle shown in Plate I, when held before the right eye in Plate II, instead of throwing a rectangular, would throw a non-rectangular, parallelogram image on the right retina; the same rectangle would also throw a non-rectangular parallel-

ogram image on the left retina. The state of refraction of the right eye would make the distorted image lean down and toward the left side, while the distorted image in the left eye would lean down and toward the right side. Cutting off the view of the left eye, the law of direction would have full sway, while the law of corresponding points would be suspended. [The image and the object would have the same shape.] Since in one eye alone the law of direction is unalterable, all lines of direction must cross in the center of retinal curvature; and the right eye, with the parallelogram image leaning down and to the left, must see the figure casting the image, not as a rectangle, but as a parallelogram leaning down and to the left. Screening the right eye while the left eye looks on the rectangle, it is seen, not as a rectangle, but as a parallelogram leaning down and to the right, the law of direction determining the shape of the figure seen by the left eye, just as it fixed the shape of the figure seen by the right eye. Fig. 1-2-3-4 is what is seen with the right eye alone; Fig. 1′-2′-3′-4′ is what is seen by the left eye alone. The moment these two eyes are allowed to look at the rectangular figure, the law of corresponding retinal points is brought into conflict with the law of direction, and the latter is modified by the former. There is no necessity for changing the visual axes when looking at the rectangle with these two eyes; but, unless some change is effected in some way, each eye would see its own parallelogram leaning down and toward the opposite side. Instantly a change does take place in both eyes, so that the two together see, not a rectangle nor a parallelogram, but a trapezoid, with the longer side above. A clear understanding of what this change is, and how it is effected, may be had by a further study of Plate II. In the right eye is shown a dotted parallelogram image a-b-c-d, of precisely the same form as the parallelogram 1-2-3-4; but in the former the upper and lower lines are parallel with the horizontal meridian. In the left eye also is shown a dotted parallelogram image a′-b′-c′-d′, of the same form as the parallelogram 1′-2′-3′-4′, with its upper and lower lines parallel with the horizontal meridian of this eye. The line c-b in the right eye bears throughout the same relation to the macula, the horizontal and vertical meridians of this eye, that the line c′-b′ does to the same parts of the left eye, and they, therefore, correspond. The greater part of the line d-a in the right eye also corresponds with the greater part of the line d′-a′ in the left eye, the parts of these lines not corresponding being their inner extremities. But the line c-d in the right eye nowhere corresponds with the line c′-d′ in the left eye, except at the points of beginning above; and the same is true of lines b-a and b′-a′, in their respective eyes. If the dotted parallelograms [for under this supposed, but im-

possible, location of the images a-b-c-d and a′-b′-c′-d′, while the vertical axes of the eyes are still parallel with the median plane of the head,

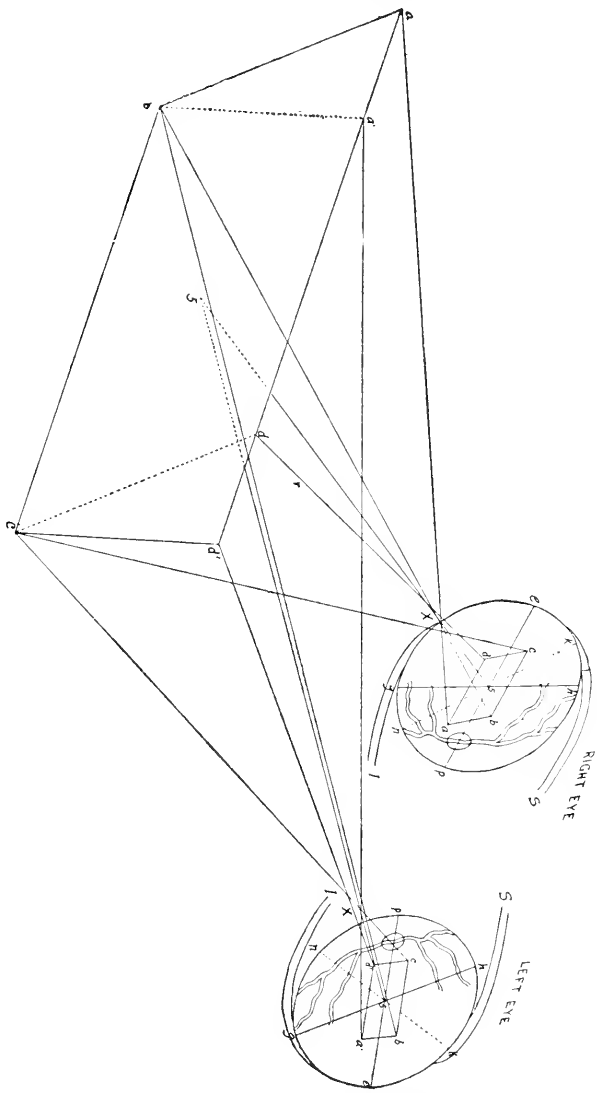


Plate III. The Retinal Images in Certain Instances of Non-parallel Oblique Astigmatism. (Savage.)

there would be two non-rectangular parallelogram figures composing the dotted trapezoid figure a-b-c-d′, precisely as shown in Plate III] could be made to coincide with the parallelogram images, the result

would be that the two eyes together would see the figure a-b-c-d′, a trapezoid, with the longer side above [in perfect obedience to both the law of corresponding retinal points and the law of visible direction. There is, however, no power that could rotate the distorted images so as to make the upper and lower borders of the images parallel with the horizontal retinal meridians, without, at the same time, making the right and left ends of the two distorted images parellel with their respective vertical meridians, in their normal relationship—the vertical axes parallel with the median plane of the head. The one power that can transform the image is the correcting cylinder which would make the image of the rectangle of the same shape shown in the eyes of Plate I. This transformation of the images, the vertical axes of the eyes remaining parallel, would make either eye alone, or both eyes together, see the rectangle as it is, as shown also in Plate I]. How this paralleling of the upper and lower borders of the distorted images with the horizontal retinal meridians is effected is shown in Plate III, in which each eye has been revolved on its visual axis by its superior oblique muscle, so that the horizontal meridian is made parallel with the upper and lower borders of the parallelogram image; and thus, as far as possible, corresponding parts of the two retinas are brought under the two dissimilar images, and the figure seen binocularly is a-b-c-d′. The part of this trapezoid seen in common by the two eyes is a′-b-c-d, the part seen by the right eye alone is a-b-a′, and that seen by the left eye alone is d-c-d′. As will be seen, the law of corresponding points has so modified the law of projection that the visual lines no longer have a common crossing point. This is anarchy, so far as projection is concerned, in these eyes.

"When the law of direction is interfered with, as a result of the conflict between it and the more imperious law of corresponding retinal points, the object seen is always in the position that it would have been in, had the images primarily fallen on the parts of the two retinas that have been rotated under them, in obedience to the supreme law of binocular single vision—the law of corresponding retinal points. The displaced images, as a result of either natural or artificial means, cover areas of the two retinas that do not correspond. In order to have binocular single vision, retinal areas that more nearly correspond, and are of the same shape and size as the images, must be brought under them. The object will be seen as though no rotation had taken place—as if the images had primarily fallen on these parts—but the lines of direction drawn from the images to the single object will not cross at the center of retinal curvature. In cases of decentration of the maculas, and in displaced images by means of prisms, all lines of direc-

tion will cross at one point, but that point will be above, below, to the outer or inner side of the true point; while in oblique astigmatism, and when the axes of correcting cylinders are displaced, no three lines of direction cross at the same point, in binocular vision.

"In like manner a plate could be made showing how astigmatic eyes, with meridians of greatest curvature converging above, would see a rectangle distorted into a trapezoid, the longer side below. In each eye there would be a parallelogram image inclining down and out. To fuse these into a trapezoid, the inferior oblique muscles would be brought into action, in order, as far as possible, to bring corresponding retinal parts under dissimilar images, which is done the moment the obliques displace the horizontal meridians so that they become parallel with the upper and lower borders of the distorted images.

"Imperfect as is binocular single vision in uncorrected oblique astigmatism, the meridians of greatest curvature either diverging or converging above, it could be effected in no other way than by a revolution of the eyes by the symmetric harmonious action of the oblique muscles."

In nonparallel oblique astigmatics the fusion effort on the part of the obliques exists from birth, until the correcting lenses have been given. This effort is relaxed at once when one eye is covered, to be resumed the moment binocular vision is attempted. There is no longer need for this abnormal action of the obliques when the astigmatism has been corrected; for the artificial emmetropia produced by the cylinders causes perfect images of the rectangle to fall on corresponding retinal areas, and the object should be seen in its proper shape, in full obedience to both the law of visible direction and the law of corresponding retinal points. That it is not thus seen, at first, is now a matter of general knowledge. The explanation for this metamorphopsic experience by nonparallel oblique astigmatics was discovered by Savage in 1890, and was first publicly announced by him in the Nashville Academy of Medicine, January 15, 1891. A little later it was published in No. 1, Volume 1, of the *Ophthalmic Record.*

Here again a free quotation may be made from *Ophthalmic Myology,* beginning with page 465:

"The careful correction of the astigmatism will counteract the distortion of the retinal images and relieve the compensating cyclotropia, but not at once; the life-time habit of the obliques can not be broken at once; but sooner or later these muscles will learn that, under the new condition (the wearing of the correcting cylinders), they must parallel the vertical axes of the eyes with the median plane of the head, in order to satisfy the law of corresponding retinal points.

"In all cases of astigmatism, one eye looking through its correcting

cylinder will see at once a rectangle as a rectangle; and if the meridians of greatest curvature are parallel—whether vertical, horizontal, or oblique—the two eyes looking through the cylinders will show no distortion of a rectangular figure. The reason for this is that, in such cases, the obliques have never done other work than the keeping of the vertical axes of the eyes parallel with the median plane of the head; therefore they have no habit to break when cylinders are given. In such cases the glasses are worn with gladness from the beginning.

"There is always metamorphopsia to annoy a patient whose astigmatism is such that the meridians of greatest curvature diverge above, when she begins the wearing of correcting cylinders, whether they be plus or minus. This distortion is easily noticed, for it is the opposite of that to which she has always been accustomed and which she may never have noticed. Seen through the correcting cylinders, a rectangle will appear as a trapezoid, with the longer side below; a level surface will slant toward her; and a vertical object will lean toward her. The metamorphopsia is due to the fact that the superior obliques, always in the habit of converging the vertical axes of the eyes in binocular vision, continue to thus converge them for a time, so that the axis of the plus cylinder and the meridian of greatest curvature do not remain in the same plane. The superior obliques, possibly because they are usually weaker than the inferior obliques, readily break from their old habit, and the metamorphopsia vanishes. In such cases it is a question of only a few hours—or, at most, a few days—until the correcting cylinders can be worn without annoyance of any kind. The old habit broken, the meridian of greatest curvature (least if a minus cylinder is used) and the axis of the cylinder lie in the same plane in binocular, as well as monocular, vision.

"When the meridians of greatest curvature converge above, the wearing of the cylinders will be attended by metamorphopsia for a much longer time, possibly because the inferior obliques, being stronger than the superior obliques, are less inclined to give up the old habit of diverging the vertical axes of the eyes, in the act of binocular vision. With either eye alone, a rectangle seen through the correcting cylinder, will be a rectangle; the floor will appear level, and a vertical object will not be inclined. In binocular vision through the cylinders a rectangle will appear as a trapezoid, with its longer side above; a level surface will slant from the patient, and a vertical object will lean from her. These appearances being new, will be easily noticed, and will often prove very annoying to the patient, unless previously told about them. Finally, the old habit of rotation will cease, and

the metamorphopsia will disappear, but only after days or weeks of constant wearing of the cylinders.

"After the disappearance of the metamorphopsia, caused by plus cylinders, whose axes diverge above, on raising the lenses a rectangle will appear as a trapezoid, with the longer side above; but if the axes of the cylinders converge above, on raising the lenses a rectangle will appear as a trapezoid, with the longer side below. The same changes in the rectangle existed before the cylinders were ever prescribed, but they were unnoticed. Now that the cylinders have corrected the misshaped images, giving perfect vision, on raising the lenses the misshaped images at once make the patient conscious of the distortion of the object."

Artificial nonparallel oblique astigmatics see, binocularly, a rectangle as a trapezoid, longer side above or below as the case may be, the result of the effort of the obliques to bring corresponding retinal areas under the distorted retinal images. The correction of the artificial astigmatism at once restores to its real shape the rectangle. The abnormal habit of the obliques has not been established except for the emergency, hence quits at once when the artificial astigmatism is corrected. The moment the ophthalmometer has located the meridians of greatest curvature in any case of astigmatism, it may be known whether there will be, or will not be, metamorphopsia through the correcting cylinders. The kind of metamorphopsia may be known, and its character and probable duration may be stated to the patient beforehand; and, at the end of the corrective work, the character of the metamorphopsia may be demonstrated, by asking the patient to describe the shape of an envelope held vertically before the eyes, and parallel with the transverse plane of the head.

"There are two methods of dealing with cases of nonparallel oblique astigmatism so as to shorten the annoying period of habit-breaking on the part of the oblique muscles. One method was suggested by Lippincott, of Pittsburg, Pa. He advises that the full error be determined under a mydriatic, and that the exact location of the principal meridians be found, which can be easily done, if the compensating cyclotropia is not complicated by a cyclophoria, by excluding one eye while testing the other; for then the one eye assumes that position which makes its vertical axis parallel with the median plane of the head. The findings, both as to strength of cylinders and positions of axes, are to be recorded. At first the cylinders given should be one-third the full strength required, but their axes must be placed according to the record. When the little metamorphopsia caused by the partial correction has disappeared, new cylinders of two-thirds the

required strength are given. The little metamorphopsia caused by these, having vanished, the full correction is given. These cause but slight metamorphopsia, and that for only a short while.

"This method is more necessary and more helpful when the meridians of greatest curvature converge above, and consequently when the inferior obliques are the muscles involved. A full correction of the astigmatism at once corrects the shape of the images, so as to make them correspond with the object. These images would now fall on corresponding retinal points, if the vertical axes of the eyes were made parallel with the median plane of the head. To thus relate the vertical axes, the inferior obliques must cease their efforts to diverge them, and the superior obliques must assume the labor of paralleling them. Work must be transferred from the inferior obliques (usually stronger) to the superior obliques (usually weaker.) The whole load can not be shifted at once; and as long as the inferior obliques continue to diverge the vertical axes, so long will the metamorphopsia remain. Righting the images one-third transfers one-third of the work from the inferior obliques to the superior obliques. This small load is kindly and quietly accepted by the superior obliques. The next step rights the images two-thirds, and transfers another one-third of the work from the inferior obliques to the superior obliques. Having become accustomed to the first transference, the superior obliques kindly take on the newly-added load. The next step fully corrects the misshaped images, and transfers the balance of the abnormal work to the superior obliques. Having already become accustomed to doing two-thirds of the work necessary for paralleling the vertical axes of the eyes, the superior obliques readily assume the remaining one-third of the load that they must now carry. For this class of astigmatics the Lippincott plan is a good one. The only objection to the method is the cost of changing the lenses.

"There is nothing to contraindicate the giving of the full correction, at once, of astigmatism in which the meridians of greatest curvature are parallel, whether vertical, horizontal, or oblique; for, in these cases, the oblique muscles have done the same work without the correcting cylinders that they must do when these are given.

"In only high degrees of oblique astigmatism, with the meridians of greatest curvature diverging above, will it be necessary to adopt the Lippincott plan; for, as a rule, the weak superior obliques are ready enough to cease doing the work of converging the vertical axes of the eyes, while the inferior obliques just as readily assume the new duty of paralleling these axes. In all cases, as soon as the obliques

learn to parallel the vertical axes of the eyes with the median plane of of the head, just that quickly does metamorphopsia vanish.

"The other method of correcting oblique astigmatism so that there shall be but little annoyance from metamorphopsia is to give at once the cylinders that fully correct the errors, and to have each lens cut so that, placed straight in the frame, its axis shall be in a plane with the meridian of greatest curvature (least curvature if the lens is a minus cylinder) when the vertical axis of the eye is parallel with the median plane of the head. However, these lenses must not be placed in their final positions in the rims at first, but each must have its axis rotated into the arc of distortion for the obliques that have been accustomed to doing abnormal work. This rotating is the reverse of the Steele rule. The rule formulated by Dr. N. C. Steele, of Chattanooga, Tenn., for the placing of the axes of cylinders in oblique astigmatism, is a good one to follow when there is cyclophoria. His rule, as applied to plus cylinders, is as follows:

" 'In those cases in which the axes of the proper convex cylinders for the two eyes diverge, place the cylinders in those positions which will give the axes the greatest divergence permitted by the tests; and in those cases in which the axes converge, place them at the points which will give them the greatest convergence permitted by the tests.'

"The Steele rule for placing the axes of plus cylinders is applicable only when these axes are within 45° of the vertical. Above the 45° point the shifting should be from the vertical; below the 45° point the shifting should be from the horizontal. In every case of oblique astigmatism with the meridians of greatest curvature diverging or converging above when there is cyclophoria the axes of plus cylinders should be displaced toward the center of the quadrants in which they are found, and the axes of minus cylinders should be shifted from the center of the quadrants in which they are found.

"The shifting to counteract the metamorphopsia is in the opposite direction from that for cyclophoria, and should be the same for the two cylinders. Every two or three days these axes should be turned a degree or two toward the location determined in the monocular test. With each turning the metamorphopsia will be so little as hardly to be noticed; and finally when the cylinders are properly located, there is no metamorphopsia. As the result of each backward turning of the axes of the cylinders, the obliques more nearly parallel the vertical axes of the eyes; and when the last turn has been made, the vertical axes of the eyes stand parallel with the median plane of the head. A wrong turning would increase the metamorphopsia.

"As the Lippincott method is specially applicable to these cases of

astigmatism in which the meridians of greatest curvature converge above, so is it with the rotation method. When the meridians of greatest curvature diverge above—whether the astigmatism be hyperopic, myopic, or mixed, unless high in degree—the full correction should be given at once, and the axes should be placed in the positions determined by the monocular tests.

"If the Lippincott method be resorted to, full acuity of vision is not obtained until the full correction of the astigmatism has been given; in the method of rotating the full-strength cylinders, vision is more or less blurred until the axes are placed at last in their final positions. As to acuteness of vision, the one method has no advantage over the other, and there is just as little annoying metamorphopsia in the one method as in the other.

"It is almost universally true that astigmatics whose meridians of greatest curvature diverge above, become speedily accustomed to the correcting cylinders, for the reason that insufficiency of the inferior obliques (minus cyclophoria) is so rare—probably not found in more than one case in two hundred. There are some astigmatics whose meridians of greatest curvature converge above, who can never wear comfortably the correcting cylinders because of insufficiency of the superior obliques (plus cyclophoria), which exists in about twenty-five per cent. of all cases.

"There are three reasons why the arcs of distortion, by correcting cylinders, for the oblique muscles, should be studied: (1) That the operator may know how to place cylinders that they may give rest to the weaker obliques in cyclophoria [as prisms are given to bring rest to weak recti muscles]; (2) that he may know how to shift the cylinders for oblique astigmatics so as to lessen the annoyance from metamorphopsia; (3) that he may appreciate the importance of having the frames, containing the cylinders that correct any kind of astigmatism, so shaped as to set perfectly straight before the eyes.

"Several curious facts may be brought forward here, and reasons have already been given why advantage should be temporarily taken of these facts in certain cases. Figure 1, in Plate IV., represents a pair of hyperopic astigmatic eyes, the meridians of greatest curvature being vertical in each eye. The plus cylinders properly placed—axes, 90° (a)—insure against strain of either the superior obliques or the inferior obliques; but let the glasses be turned in their rims so that the axis of the right shall stand at 80° (b) and the axis of the left at 100° (b), images will be distorted, as shown in Plate II., which would necessitate strain on the part of the superior oblique muscles. The distortion of the images would increase, and the strain on the

superior obliques would be greater, as the axes are revolved farther away from the vertical, the maximum being reached at 45° (c) for the right eye and 135° (c) for the left eye. Passing these points, the distortion grows less, until at 180° (d) for each eye, it disappears.

"Figure 2 represents the same pair of eyes. If now the axis of the right cylinder should be revolved from 90° (a) to 100° (b) and that of the left cylinder from 90° (a) to 80° (b), the distortion of images

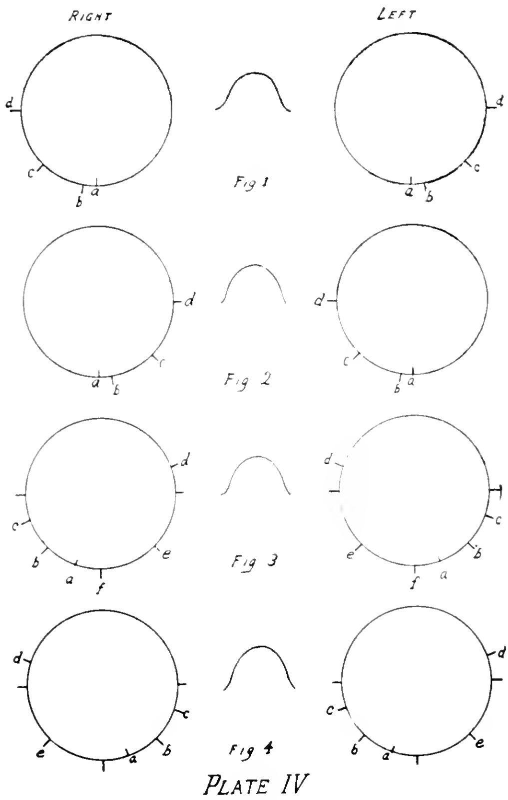


Plate IV. Diagrams of Visual Distortion in Oblique Astigmatism. (Savage.)

would be such as to call into activity the inferior obliques, so that there might be binocular single vision. This distortion would reach its maximum when the axis of the right cylinder stands at 135° (e) and that of the left cylinder at 45° (e), again lessening as the axes are made to approach the horizontal, where the distortion ceases.

"Figure 3, Plate IV., represents a pair of hypermetropic astigmatic eyes with the meridian of greatest curvature of the right at 70° (a) and that of the left at 110° (a). (In all the figures of Plate IV., Plate

V., and Plate VI., the mark within the circle shows the location of the meridian of greatest curvature.) These meridians, converging above, would cause strain of the inferior obliques, which would be relieved by the correcting cylinders, axis of the right at 70° (a) and of the left at 110° (a). A revolution of the axis of the right cylinder to 45° (b) and that of the left cylinder to 135° (b) would so displace the images as to call into action the superior obliques, the displacement increasing as the axes are moved until these points (b for each eye) are reached. Continuing the revolution of the cylinders in the same directions, the displacement lessens, and disappears entirely when the axis of the right reaches 20° (c) and that of the left reaches 160° (c), when the necessity for over-action of the obliques no longer exists. If the axes of the cylinders are moved from their correct positions (70° for the right eye and 110° for the left eye) to 90° (f) for each eye, images will be so displaced as to call into compensating activity the inferior obliques. The maximum of displacement would be effected when the axis reaches 135° (e) in the right eye and 45° (e) in the left eye. Continuing the revolution in the same directions, the displacement would grow less, and finally disappear when the axis of the right eye stands at d, and that of the left eye at d, each 20° above the horizontal. As will be seen, the arc of distortion, so as to throw strain on the superior obliques, is 50° (from 70° to 20° in the right eye and from 110° to 160° in the left eye), while the arc of distortion that would throw strain on the inferior obliques is 130° (from a to d).

"Figure 4, Plate IV., shows the meridians of greatest curvature of these hypermetropic astigmatic eyes at 110° (a) for the right and 70° (a) for the left. These meridians, diverging above, would call into compensating activity the superior oblique muscles. Correctly chosen and properly placed cylinders, by correcting the distortion of the images, would remove the necessity for the performance of the complicated function of the superior obliques. Displacing the axes of these cylinders the right to 135° (b) and the left to 45° (b), would cause a maximum distortion of the images, of the kind to call into action the inferior obliques. Continuing the revolution of the cylinders, the distortion would disappear when the axis of the right reaches 160° (c) and that of the left reaches 20° (c). Should the axes of the cylinders be revolved from their proper places—at 110° (a) in the right and 70° (a) in the left—to 90° (f) for each eye, the images would be so changed as to call into harmonious activity the superior obliques. The maximum distortion would occur when the axis of the right is at 45° (e) and that of the left at 135° (e). Continuing the revolu-

tion, the distortion would disappear when the axes reach the points d above the horizontal meridians. In this case the arc of distortion causing activity of the inferior obliques is 50° (from a to c), while the arc of distortion that would throw strain on the superior obliques is 130° (from a to d). If in this pair of eyes the meridians of greatest curvature had been at 130° for the right and 50° for the left, the arc of distortion that would call the inferior obliques into action would

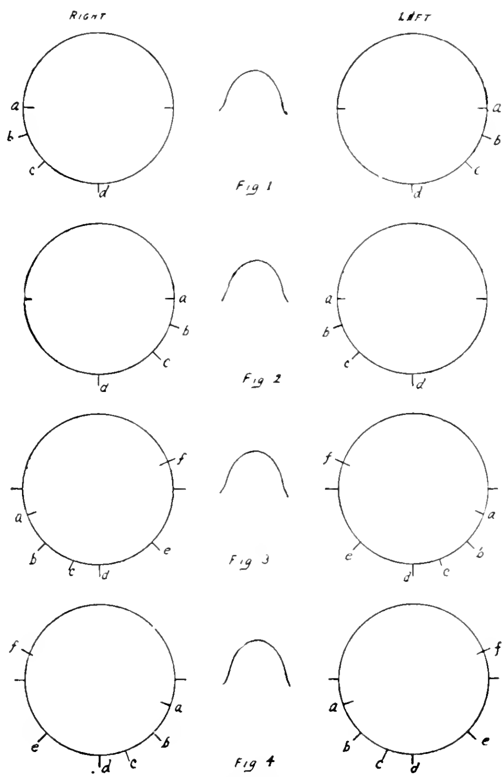


PLATE V

Plate V. Diagrams of Visual Image Distortion in Oblique Astigmatism.

be only 10°, while the one that would cause activity of the superior obliques would be 170° (180° less 10°).

"Figure 1, Plate V., represents hypertropic astigmatic eyes, the meridians of greatest curvature being 180° (a) in each eye—a condition that, in itself, would not call either the superior obliques or the inferior obliques into activity. The correct plus cylinders—axes, 180°—would sharpen the blurred, but not distorted, images. Displacing these axes in the lower temporal quadrants would so distort the

images as to throw into action the superior obliques; and the maximum of distortion would be effected when the axes reached 45° (c) in the right eye and 135° (c) in the left eye. With the axes turned to 90° (d), there would be no distortion of images, though there would be blurring, as in all cases of displaced cylinders.

"Figure 2, Plate V., represents the same pair of eyes shown in Figure 1. Revolving the axes of the correcting cylinders in the lower nasal quadrant, would so distort images as to call into action the inferior oblique muscles, the maximum being affected when the axes stand at 135° (c) for the right eye and 45° (c) for the left eye, the distortion lessening as the axes approach, and disappearing altogether when they reach, 90° (d).

"A comparative study of Fig. 1. and Fig. 2 of Plate IV., with Fig. 1 and Fig. 2 of Plate V., will show that, in hypermetropic astigmatism with the meridians of greatest curvature either vertical or horizontal, a revolution of the axes of the cylinders in the lower temporal quadrant will distort images (as of a rectangle) down and in, and will thus call into harmonious action the superior obliques; and it will also show that a revolution of the cylinders in the lower nasal quadrants will so displace the images as to call into harmonious action the inferior obliques."

"Fig. 3, Plate V., represents a pair of hypermetropic astigmatic eyes with the meridian of greatest curvature for the right eye at 20° (a) and that of the left eye at 160° (a). Since these meridians converge above, the uncorrected condition would cause harmonious action of the inferior obliques. Properly chosen and correctly placed cylinders, axes at 20° (a) for the right eye and 160° (a) for the left eye, would relieve the distortion of the images and do away with the necessity for the compensating action of the inferior obliques. Revolving the axis of the right cylinder from 20° (a) to 45° (b) and that of the left cylinder from 160° (a) to 135° (b) would cause a maximum displacement of images in such a way as to call into action the superior oblique muscles, the distortion disappearing when these axes reach 70° (c) for the right eye and 110° (c) for the left eye. Passing 70° (c) in the right eye and 110° in the left eye, the distortion becomes reversed, so that the strain will be thrown on the inferior obliques, the maximum being attained when the axis of the right stands at 135° (e) and that of the left at 45° (e). The distortion decreases as the axes are still farther turned in the same directions, and disappears at the end of the arc of 130° (from c to f) when they coincide with the meridians of greatest curvature. Thus the arc of distortion involving

the superior obliques is 50° (from a to e), while that involving the inferior obliques is 130° (from e to f).

" The eyes (hypermetropic astigmatic) represented by Fig. 4, Plate V. have their meridians of greatest curvature at 160° (a) in the right and 20° (a) in the left. These meridians diverging above would result, in the uncorrected case, in calling into harmonious action the superior obliques. Proper cylinders with the axis of the right at 160° (a) and that of the left at 20° (a) would correct the distortion of the images and relieve the strain on the superior obliques. A turning of these cylinders in the arcs a-c would distort the retinal images so as to bring into action the inferior oblique muscles, the maximum distortion existing when the axes are at b. Continuing the revolution from c, the distortion becomes reversed, and, as a consequence, the superior obliques are brought into activity, the maximum being attained when the axes reach e. As the axes are revolved farther, the distortion lessens, and finally disappears when they stand at f, again coinciding with the meridians of greatest curvature. In this pair of eyes the arc of distortion involving the inferior obliques is 50° (from a to e), while that involving the superior obliques is 130°, the maximum of distortion in both instances being attained when the halfway point of the arc is reached by the axis of the cylinder.

"A comparative study of any two, or all, of the figures in Plate IV. and Plate V. will show that the arc of distortion, by corrective plus cylinders, involving the superior obliques, is always in the lower temporal quadrant, or upper nasal quadrant wholly or in greater part; and if entirely within this quadrant, its length is always twice the distance from the meridian of greatest curvature to the 45° point of the quadrant, the other half being on the opposite side of the latter. In like manner it will be seen that the arc of distortion involving the inferior obliques, by a revolution of corrective plus cylinders, is always in the lower nasal quadrant wholly or in greater part; and if entirely within the quadrant, its length is twice the distance from the meridian of greatest curvature to the 45° point of the quadrant, the other half being on the opposite side of the latter. When the arc of distortion involving the superior obliques is 90°, that involving the inferior obliques is 90°, and vice versa; when the arc of distortion involving the superior obliques is less than 90°, the arc involving the inferior obliques is always the difference between the former and 180°, and vice versa. The maximum of distortion is always attained when the axis of the cylinder is at the halfway point of the arc. [In cases of myopic astigmatism the very opposite of what is said above about the arcs of distortion for the superior and inferior obliques, is true.]

"Fig. 1, Plate VI., represents a pair of hypermetropic astigmatic eyes, the meridian of greatest curvature of the right eye at 45° (a) and that of the left eye at 135° (a). These meridians converging above would cause such distortion of images as to throw into harmonious action the inferior oblique muscles. The proper cylinders, correctly placed—the axis of the right at 45° (a) and the axis of the left at 135° (a)—would counteract the distortion and relieve the inferior obliques of the necessity of over-acting. Revolving the axes of the correcting cylinders in either direction would so distort images as to call into harmonious action the inferior oblique muscles. Since the arc of distortion for the superior obliques in this case is nothing, the arc of distortion for the inferior obliques is 180°, from a to d in

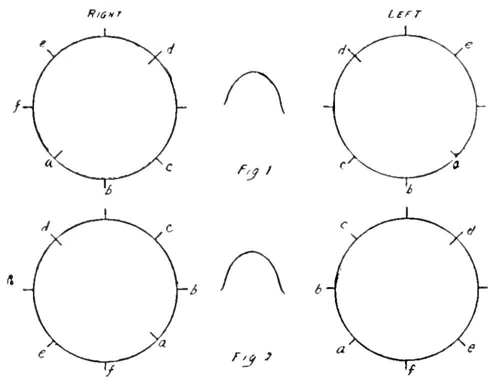


PLATE VI

Plate VI. Diagrams to Illustrate Retinal Image Distortion in Oblique Astigmatism. (Savage.)

either direction, the maximum of distortion being attained, respectively, at c above and at e below.

"Fig. 2, Plate VI., represents a pair of the same kind of eyes, but with the meridian of greatest curvature at 135° (a) for the right eye and 45° (a) for the left eye. These meridians diverging above, the refraction is such as to distort images so as to call into harmonious action the superior obliques. As in the other case, the correct cylinders, properly placed, counteract the distortion and relieve the superior obliques from action. Rotating the axes of these cylinders in either direction from a would so distort images as to call into activity the superior obliques. In this case the arc of distortion for the inferior obliques is nothing, and, therefore, the arc of distortion for the superior obliques is 180°, from a to d in either direction, the maximum being attained at c above and at e below.

"In the adjustment of cylinders for the correction of astigmatism—whether it be vertical, horizontal, or oblique—a knowledge of the arcs of distortion by displaced cylinders is of great importance. Patients should be impressed with the absolute necessity of keeping the rims containing the glasses in such relationship to each other that a straight edge would pass through the following four points: the two points where the temple pieces join the rims and the two points of attachment of the nose bridge to the rims. If the frames should be so bent that the long axis of each lens [a plus cylinder] would lean down and out, and the astigmatism is according to the rule, the cylinders would be displaced in the arc of distortion for the inferior obliques, which, usually, would be borne fairly well; but when the astigmatism is against the rule, this displacement would be in the arc of distortion for the superior obliques, and would cause much annoyance. This would be true, whether the astigmatism were hyperopic, myopic, or mixed.

"If the frames should be so bent that the long axes of the lenses pointed down and in, the astigmatism being according to the rule, the axes of the plus cylinders would be displaced in the arcs of distortion for the superior obliques, and would cause trouble; but if the astigmatism were against the rule, the displaced axes would be in the arcs of distortion for the inferior obliques, and but little trouble would result unless the displacement should be considerable."

The leaning, or displacement of minus cylinders, because of want of proper alignment of the containing frames, would have a meaning the opposite of that set forth in the study of plus cylinders thrown out of position.

The action of the obliques in uncorrected nonparallel oblique astigmatism and in corrected astigmatism when the cylinders have been misplaced because of bent frames, or because of incorrect placing of cylinders in straight frames, is best designated by the expression "compensating cyclotropia," one of the worst forms of eye-strain.

What remains to be said on "oblique astigmatism" will be of more than historic interest. The late F. C. Hotz, at a meeting of the Chicago Ophthalmologic Society in 1895, thought that he had demonstrated that retinal images are not distorted by oblique astigmatic eyes. It seems that his auditors, to a man, were also convinced by his demonstration. He rendered his camera astigmatic by placing in front of its lens a + 2. cylinder with its axis oblique (at 45°). The object on which his camera was focused was an illuminated horizontal slit in a metal screen, the length of the slit being only one inch, and it was several feet removed from the camera. On darkening the room he and his fellows saw the bright but very short image of the illu-

minated slit, and they all pronounced this image perfectly horizontal. On the strength of this experiment with his camera, and encouraged by the acquiescence of his colleagues of the Society, he wrote a communication for publication in the *Annals of Ophthalmology and Otology*, in which he strongly and severely criticized Savage's teachings on the action of the oblique muscles in oblique astigmatism. He said that the premise was false and that the conclusion could not be true. To prove that the premise was false he related his demonstration with the camera before the Chicago Ophthalmological Society, as above outlined. But he did not stop with the revelation of his camera, as may be shown in the following quotation from his paper: "It is, therefore, evident that neither experiments, nor clinical observations, nor the law of physiological optics, sustain the doctrine of the obliquety of retinal images and the necessity of any action of the oblique muscles in oblique astigmatism." Savage replied to this criticism in the next issue of the *Annals* (July, 1895), and also wrote Hotz that he would not have been deceived by his camera if his slit had been longer and had been crossed at its center by another slit of the same length, the two slits being at right angles to each other. A few months later Hotz, having been elected President of the Ophthalmological Society, invited Savage, whom he had so severely criticized, to come to Chicago on a certain date and address the Society on "Oblique Astigmatism." The invitation was accepted. The occasion was the annual dinner of the Society, and Savage found himself the guest of honor. At the end of the feast the speaker of the evening was introduced and his subject was announced as "Oblique Astigmatism," at which announcement his fellow members must have been astonished, remembering his camera demonstration of a few months previous. At the end of the address President Hotz reached under the table and, bringing forth his camera, arose and said that a few months ago he thought that he had demonstrated with this camera the falsity of Savage's teachings about oblique astigmatism, and that he had unwittingly misled them into agreement with him. He then said that with this same camera he was now ready to prove that he was wrong in his criticism and that Savage had taught the truth. He then pointed his camera towards a chart on which had been drawn two lines, one vertical and the other horizontal, crossing each other at the center. These lines were then carefully focused on the ground-glass plate by means of the spherical lens only, the image formed showing the two lines crossing each other at right angles. His colleagues were asked to view the undistorted image. He then placed in front of the spherical lens the same cylinder (+2.00 at 45°) which he had used at the former meeting. The image showed

the two lines no longer at right angles, but each was rotated from the axis of the cylinder. His colleagues were asked to observe the distortion, which they did with evident astonishment. The guest of honor was no less astonished, for up to that moment he had not known of any change in Hotz' views on the subject.

Hotz' promise to him whom he had criticized that he would give as wide publicity to his retraction as he had given to the criticism, was never fulfilled for the reason that, soon after, he became a very sick man and had to give up his professional duties, dying not many

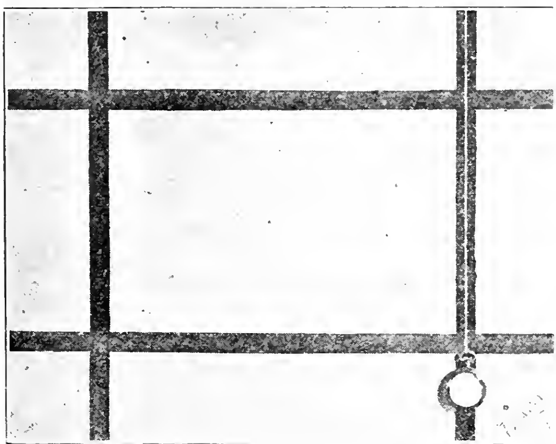


Fig. 9. Photograph of a Perfect Rectangle. (Lowry.)

months thereafter. The real greatness of the man was shown by the incident recorded above.

In the same year (1895) in which Hotz published his criticism, Harold Wilson, of Detroit, became busy with his camera, his purpose being to prove that there is no distortion of retinal images in oblique astigmatic eyes. He made five photographs of a church spire under the following conditions: one without an astigmatic lens; one with an astigmatic lens axis at 90°; two with the astigmatic lens at 45°; and two with the astigmatic lens at 135°. In these photographs he studied the axis of the spire and pronounced it vertical in each of the pictures. From these photographs he had half-tone cuts made and used them in a criticism which he published in the *Journal of Ophthalmology, Otology and Laryngology* (July, 1895), the burden of which was that the premise assumed by Savage was shown to be false by the several photographic reproductions used for illustrating his communication. His conclusion was that, since there is no distor-

tion of retinal images in oblique astigmatism, the oblique muscles have no such function to perform as that ascribed to them by Savage.

Wilson's error was in the fact that he failed to study the axis of the spire as related to its base. In his first two illustrations he would have found the axis and the base-line at right angles; in the second two he would have found the upper-left angle acute; and in the remaining two he would have found the upper-left angle obtuse. His attention was called to this error into which he had fallen, and in a private letter he made acknowledgment; but so far as known by the writer, he made no public correction of his criticism.

Under the stimulus of the Wilson criticism, based on what he supposed his camera showed, W. B. Lowery, then a private student of

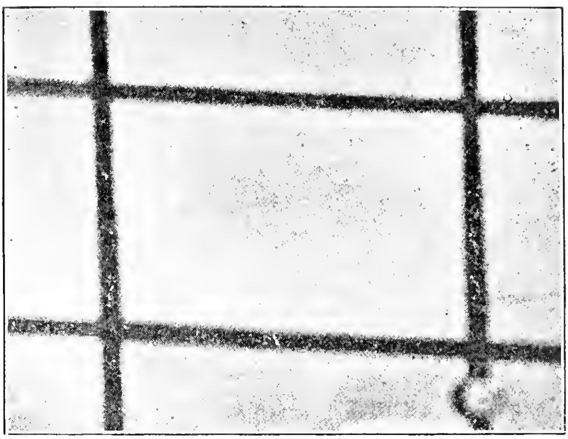


Fig. 10. A Rectangle Photographed with a Minus 3 D. Cylinder, Axis 45°, in Apposition to the Camera Lens. (Lowry.)

Savage, betook himself to his camera and made six photographs of a perfect rectangle. Lowery's photographs and his own words used in describing them, as published in the *Ophthalmic Record,* August, 1895, are here reproduced.

"It has often been noted that the camera obscura is very strikingly similar, in its mechanism, to the human eye. In this simple optical instrument we have a mechanical eye, so far as refraction is concerned. If we compare to the eye the component parts of the photographic camera, which is merely a camera obscura with a device for receiving the image on a sensitized plate, we find the refractive media of the former correspond to the photographic lens; the iris, to the stop; the accommodation, to the focusing apparatus; and the retina, to the ground glass. Focus the camera properly, and we have the emmetropic

eye. By placing a concave cylindrical lens, axis at 90°, in apposition to the photographic lens, we have simple hypermetropic astigmatism according to the rule; if we place the axis at 180°, we have simple hypermetropic astigmatism against the rule; if we place the axis anywhere between the vertical and horizontal, we get oblique astigmatism. Whether or not the image will be oblique on the ground glass will be seen later.

"To illustrate these points, I have made the accompanying photographs with a rapid rectilinear lens, used in the Rochester Optical

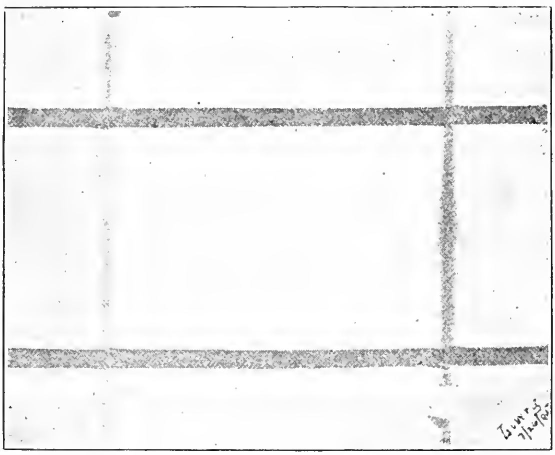


Fig. 11. Photograph of a Rectangle with a Minus 3 D. Cylinder, Axis 90°. (Lowry.)

Company's 5 x 7 midget camera. The camera was not moved or changed in any way for the first five photographs. Fig. 14 was made at another time. The rectangle was made mathematically accurate on a piece of cardboard 24 x 30. The lines, one inch wide, are prolonged beyond the rectangle to show more clearly the obliquity of images that may be produced by the cylinders obliquely placed. The watch is used as a plumb, and is seen in the same position in all. The photographs are not inverted as the images would be on the ground glass or the retina.

"In Fig. 9, no cylindrical lens is used, and we get a perfect rectangle, sharp and distinct in its outlines, as would be seen by an emmetropic eye.

"In making Fig. 10 a minus 3 D. cylindrical lens is placed just in front of, and in apposition to, the photographic lens, with its axis at

45°.* A plus 1.50 D. spherical lens is used with the cylinder in order to give the middle of the focal interval without changing the camera. In this the vertical and horizontal lines are equally indistinct. The

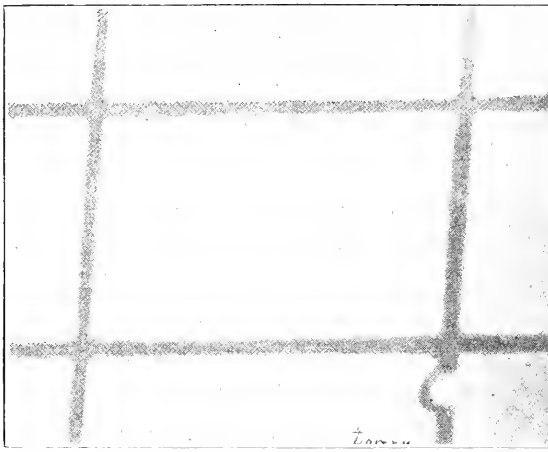


Fig. 12. Photograph of a Rectangle with a 3 D. Cylinder, Axis 135°. (Lowry.)

vertical lines deviate to the left at the top, and to the right at the bottom, while the horizontal lines are depressed at the right and ele-

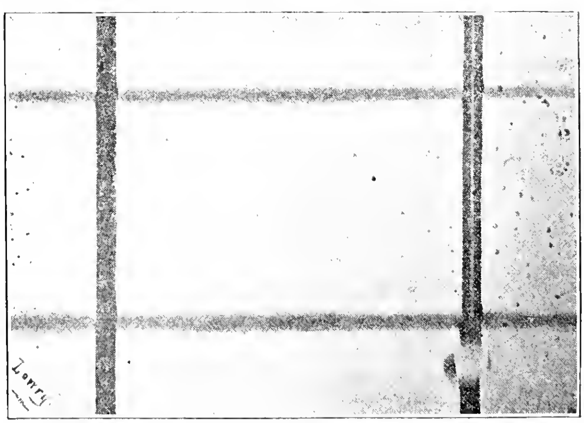


Fig. 13. Photograph of a Rectangle by the Addition of a Cylinder Minus 3 D., Axis 180°. (Lowry.)

vated at the left. The plumb shows that the card is in just the same position as in Fig. 9, and the camera has not been moved from its

* These prints are all the reverse of the images, therefore the reverse of the object as it would be seen.—(G. C. S.)

original position. This picture is clearly a non-rectangular parallelogram.

"If the axis of the cylinder be changed to 90°, we get Fig. 11, which represents simple vertical hypermetropic astigmatism. This is made without the plus 1.50 D. sphere and without the camera being changed in the least from its position in Fig. 9 and Fig. 10. The meridian of greatest curvature here is at 90°, with the least at 180°. It is a perfect rectangle, with its horizontal lines sharply cut and the vertical very distinct.

"Now if we place the axis of the cylinder at 135°, again adding the plus 1.50 D. sphere, a non-rectangular parallelogram is formed with its sides deviating in the opposite direction to those in Fig. 10. This

Fig. 14. Same as Fig. 10, But Without the Plus 1.50 Sphere Added to the Cylinder. (Lowry.)

is shown in Fig. 12. Every part is equally indistinct, and nowhere are the lines at right angles as in the original.

"By placing the axis of the cylinder at 180°, without the plus 1.50 D. sphere, we produce simple hypermetropic horizontal astigmatism, the effect of which is illustrated in Fig. 13. Here we have the meridian of greatest curvature at 180°, and the least at 90°. We obtain a perfect rectangle, with its vertical lines clear and its horizontal very indistinct, in contradistinction to Fig. 39.

"Fig. 14 is the same as Fig. 10 without the plus 1.50 D. sphere to give the focal interval, nor is the camera refocused to give it. This photograph was made at a different time, and the camera was not in exactly the same position as for the other five. An eye with the meridian of greatest curvature at 45° and 3 D. of simple hypermetropic

astigmatism would see the object as shown in this figure, if, under the influence of a mydriatic or in old age, it were relieved of all ciliary action. The rhomboidal figures are seen very clearly here at the angles and on the watch.

"Suppose one of the meridians of greatest curvature to be at 45°, and the other at 135°, one image would be seen as in Fig. 10, and the

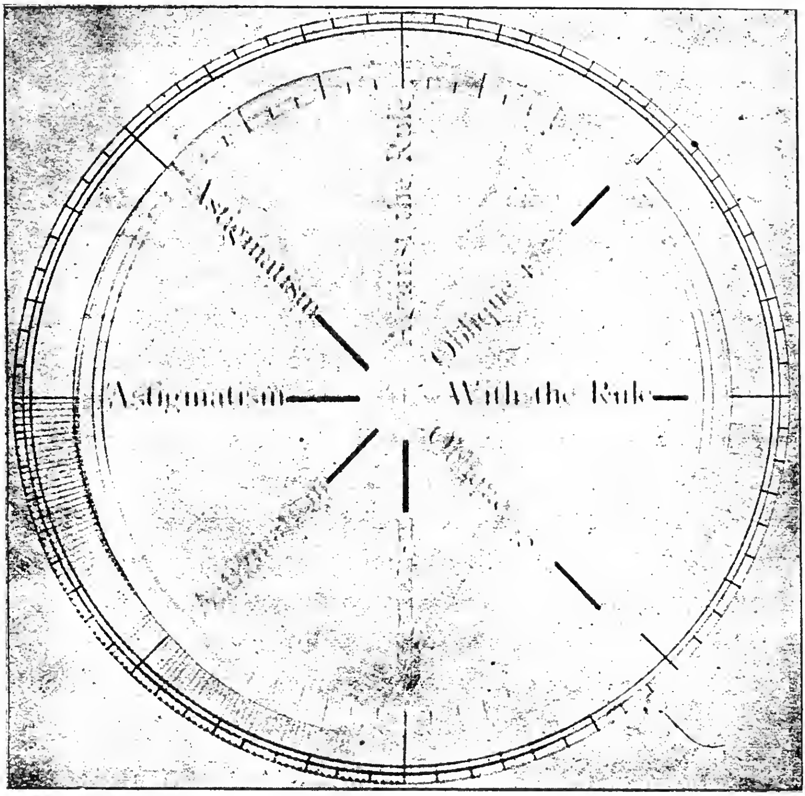


Fig. 15. Diagram to Show the Effect of Oblique Astigmatism on Retinal and Photographic Images. (Perry.)

other as in Fig. 12; in obedience to the law of corresponding retinal points, we would have these two figures superimposed, forming a trapezoid. If the meridians diverged above, we would have the long side above, and the short side below. In this form of astigmatism we would not only have a ciliary strain, but the superior obliques would make an attempt to bring the harmonizing parts of the two retinas under the dissimilar images in order to have a single object. If the

meridians converged above, the short side of the trapezoid would be above, and the long side below. This fusion of dissimilar parallelograms into a trapezoid, long side below, would be effected by the inferior obliques.

"But the bone of contention has been principally the question of the deviation or the non-deviation of the image on the retina in oblique astigmatism. Others have proved it by the laws of optics, by clinical experience, and by logical reasoning; and it seems to me that my photographic demonstrations have added very conclusive evidence to the theory that, in oblique astigmatism, the retinal images of vertical and horizontal objects deviate from their normal direction."

Almost simultaneously with Lowry's photographic study, therefore soon after Hotz and Wilson had tried the camera and had published their conclusions unfavorable to the distortion of retinal images by oblique astigmatism, Dr. Perry, of Oneida, N. Y., betook himself to the camera, with the result shown in the accompanying half-tone cut, Fig. 15.

Dr. Perry's own words, descriptive of this cut, are as follows:

"Fig. 15 was produced by taking a photograph of the graduated circle with printed words as shown; and then, without moving camera or object, placing a .50 D. cylindrical lens in front of the objective and exposing a second negative, and, when the photographs were finished, cutting away the outer circle from the astigmatic print and pasting it over the other in such a way as to make the horizontal and vertical lines, respectively, coincide on the two prints. If the cut is held so that the line of the print reading 'Astigmatism Oblique, 135°,' is horizontal, it will be observed that the distortion of the field is such that this particular line is moved along the scale nearly two degrees, while the line which is perpendicular to it is moved an equal distance, but in contrary direction. This shows what must happen to a retinal image in oblique astigmatism."

Experiments, clinical observations, the law of physiologic optics, and the camera all sustain the doctrine of the distortion or displacement of retinal images in oblique astigmatism. The law of corresponding retinal points compels definite action of the oblique muscles in order to harmonize, as perfectly as possible, the two distorted retinal images in all cases of nonparallel oblique astigmatism. Further work with the camera, after the method of Perry, will enable one to know how much the distortion of images is in a given case of oblique astigmatism, and through what arc the obliques must rotate the eyes, on their visual axes, in order to imperfectly fuse the images in nonparallel oblique astigmatism.

At no distant day, some one, profoundly interested in physiologic optics and skilled in mathematics, will discover a formula by means of which the degree of displacement of retinal images in any given case of astigmatism may be calculated, and this calculation will agree with what the camera can show when used after the method of Perry.

The discovery and study of cyclophoria developed the question, "Can any other condition than cyclophoria cause a horizontal line to appear oblique?" The answer to this question was the re-discovery of the fact that oblique astigmatism will thus change the apparent direction of a horizontal line. As already set forth herein, the credit for this discovery, made in 1889, must go to J. A. Lippincott, then of Pittsburgh, Pa., which fact had been learned, but forgotten, by the writer of this paragraph. He, independent of Lippincott, solved the same problem in a more extended way and published same in Number 1, Volume 1, of the *Ophthalmic Record* (1891); and later (in 1894) in a paper read before the Eighth International Congress of Ophthalmology at Edinburgh. Lippincott did not discover the compensating cyclotropia necessarily associated with all cases of uncorrected nonparallel oblique astigmatism, the imperious law of corresponding retinal points compelling it and controlling it.

The study of cyclophoria not only acted on the study of oblique astigmatism, but the latter reacted on the former, in that, out of it came the discovery of the treatment and cure of cyclophoria by exercising the weak obliques by means of cylinders obliquely placed, using them on the same principle, and after the same method, that prisms are used for exercising weak recti muscles.

In announcing the discovery of cyclophoria—insufficiency of the obliques—in the January (1891) issue of the *Archives of Ophthalmology* this language was used: "There is not now, nor can I see how there can ever be, any relief for this trouble." Eighteen months later the curative treatment emerged from the study of oblique astigmatism, but this was one year after the discovery of compensating cyclotropia.—(G. C. S.)

Oblique de l'œil, Grand. (F.) The superior oblique muscle.

Oblique de l'œil inférieur. (F.) The inferior oblique muscle.

Oblique de l'œil, Supérieur. (F.) The superior oblique muscle.

Oblique hemiopia. This rare form of visual defect due to partial involvement of the optic chiasm has been recently studied chiefly by Purves Stewart and A. D. Griffith (*Lancet*, July 15, 1916; abstract in *Ophthalmoscope*, p. 542, Oct., 1916) in the person of a man, aged 24 years, who came under observation one week after injury. Apart from other wounds, one metallic fragment had entered through the

right upper eyelid and destroyed the right eye. It had lodged within the cranium, where radiography showed it lying about a quarter of an inch above and a quarter of an inch in front of the upper limit of the sella turcica. It had crossed the mesial plane and lay half an inch to the left of it. The patient suffered from septic meningitis, and examination of the exact ocular condition was at first not possible. It was early noted, however, that in addition to the destruction of the right eye, the left pupil was widely dilated and insensitive to light. It was also stated that the patient was completely blind. Twelve days after the injury, when he was able to reply to questions, it was found that the left eye had no perception of light and had a wide and insensitive pupil. Optic disc and fundus were at this time normal.

A month after the injury, and shortly after the right eye had been excised, some vision had returned in the left nasal field. Eventually, some two months after injury, it was possible to make a more careful examination. The optic disc was now atrophic. The pupil was widely dilated, but showed a hemiopic reaction. The boundary between the blind and seeing portion of the field ran through the 120° not through the 90° meridian, and apparently the fixation point was affected. Vision gradually improved from hand-movements to 5/60 and slight gains of seeing field took place. The lesion involved the mesial portion of the left optic nerve at its junction with the chiasma. It affected, the authors say, mainly the fibres destined for the right optic tract. Some of them, however, escaped, namely, those corresponding to the upper and mesial sector of the blind field, also a smaller number corresponding to the area just above the horizontal plane, directly outwards from the fixation point. These are represented as a dagger-like extension of the seeing field into the blind field. In addition, a number of fibres destined for the left optic tract were also implicated, namely, these corresponding to the lower and mesial sector of the right half of the visual field; that is to say, those roughly included between the lower 90° and 120° meridian, although the line of demarcation was not straight either above or below the horizontal.

See, also, **Hemiopia,** p. 5766, Vol. VIII of this *Encyclopedia.*

Oblique illumination. See **Examination of the eye,** p. 4602, Vol. VI of this *Encyclopedia.*

Oblique, Inferior. This short muscle arises from the orbital plate of the superior maxilla, close to the outer border of the lachrymal groove, and passes outward and backward beneath the rectus oculi inferius to be inserted into the posterior and external surface of the eyeball. See **Anatomy of the eye.**

Oblique muscles. See **Muscles, Ocular,** as well as p. 363, Vol. I of this *Encyclopedia;* also **Oblique astigmatism.**

Oblique pencil. In *optics,* a pencil of light whose axis or chief ray is inclined to the normal of a surface, or to the optical axis of a mirror or lens.

Oblique ray. In *optics,* a ray of light whose direction differs from the normal to a surface, or that is inclined to the optical axis of a mirror or lens.

Oblique rotation. See **Muscles, Ocular.**

Obliquity of lenses. As pointed out by Weeks, Jackson and others, when lenses are placed obliquely before the eye they produce the effect of cylinders with the axis of the artificially produced astigmatism corresponding to the meridian around which the lens is rotated to make it oblique. This act also increases the refraction of the sphere.

The amount of error in the obliquity of strong lenses is considerable, as will be seen by the following table of Jackson:—A lens of + 10 D. rotated around its horizontal axis:

$$10^\circ = +10.10 \circ + 0.37 \text{ cy. ax. } 180^\circ$$
$$20^\circ = +10.40 \circ + 1.38 \text{ cy. ax. } 180^\circ$$
$$30^\circ = +10.93 \circ + 3.65 \text{ cy. ax. } 180^\circ$$

It will be seen that the increase in error is proportionately more rapid with the increase in degree of obliquity. Jackson remarks that patients sometimes look obliquely through the edge of their glasses in order to get the effect of a stronger lens than has been prescribed for them, or a cylindrical effect that their lenses do not give. To prevent this he advises the use of the periscopic form of lens.

Obliquus accessorius. An anomalous accessory superior oblique muscle of the eye, resulting from the separation of the muscle into two parts.

Obliquus oculi accessorius. GRACILLIMUS ORBITIS. OBLIQUUS ACCESSORIUS. An anomalous accessory superior oblique muscle of the eye, resulting from the separation of the muscle into two parts.

Obliquus oculi inferior (seu minor). Inferior oblique muscle.

Obliquus oculi major (seu superior). Superior oblique muscle.

Obnubilate. To obscure or darken.

Obscure radiation. Radiation of waves too long or too short to affect the eye.

Obscure rays. The invisible heat rays.

Obstetric ocular injuries. See **Birth injuries,** p. 999, Vol. II of this *Encyclopedia;* also **Pregnancy.**

Obstruction of central artery. See p. 4287, Vol. VI of this *Encyclopedia.*

Obturateur. (F.) Shutter.

Obvert. To turn towards.

O'Carolan, Turlaugh or Turlough. A blind Irish bard. He was born at Nobber, Westmeath, in 1671, and lost his sight from smallpox at a very early age. When twelve years old, he took a few lessons on the harp, but soon rejected further instruction, and developed his musical faculty for himself. He became well known as a composer of music for the harp, and to the present day are played his "Irish Lamentation" and "Farewell to Music."

He married a Mary Maguire about 1691. She died in 1733, and O'Carolan himself died five years later. His remains were interred in the parish church at Kilrouan, Ardagh.—(T. H. S.)

Ocecation. An obsolete term for becoming blind; blindness.

Occhiali protettivi. (It.) Protective glasses.

Occhiali stenopeici. (It.) Stenopaic glasses.

Occhio amaurotico. (It.) An amaurotic eye.

Occipital syndrome. See **Gunshot injuries of the ocular apparatus,** p. 5666, Vol. VII of this *Encyclopedia.*

Occipito-frontalis muscle. It arises from the mastoid process and superior oblique line of the occiput and the angular process of frontal bone and is inserted into the occipitofrontal aponeurosis. Its nerve supply is the posterior auricular, minor occipital, and facial nerves, while its action is to move the scalp and wrinkle and raise the eyebrow.

Occlusion of one eye. Shutting off the vision of one eye for a time has decided effects upon the eye so treated. as well as upon the *muscle balance* and upon binocular vision. Marlow (*N. Y. State Journal of Med.*, Nov., 1915) uses this method as an office procedure for ascertaining the relative position of rest, but states that it is not a method for routine use. The cases must be selected and are usually in patients with inveterate asthenopia, who have been unrelieved by refractive treatment. The occlusion has been kept up for varying periods of time, from one to ten days, a good working average being a week. The method adopted for putting the procedure into practice has consisted in replacing one of the patient's lenses with a ground glass. It is necessary to occlude the proper eye. This may be decided by the visual acuity, the more defective eye being covered, or in case where there is no difference by allowing the patient to decide whether he is left-eyed or right-eyed by looking at a distant light, with both eyes open, through a ring held at arm's length. If the light is sighted with the right eye the left is occluded.

At the end of the occlusion period, lenses correcting the refraction and a Maddox rod are placed in a trial frame, the patient is made to close his eyes, the occluding glasses removed and the trial frame sub-

stituted for them. The patient opens his eyes and the deviation is measured in the usual way. He reports on ninety cases and finds percentages obtained are as follows: Parallelism, 7 per cent.; divergence without hyperphoria, 17 per cent.; divergence with hyperphoria, 41½ per cent.; total, 58 per cent. Convergence without hyperphoria, 4½ per cent.; convergence with hyperphoria, 5½ per cent.; total, 10 per cent. Hyperphoria without lateral deviation, 24½ per cent.; R. 9 per cent.; L. 15½ per cent.; hyperphoria with lateral deviation, 47 per cent, or 71½ per cent. of all cases. A latent deviation is followed in many cases by the manifestation of a higher degree of error. It is also true that such manifestation occurs with greater rapidity and completeness if the binocular function is entirely annulled by occlusion, and the occluded eye is allowed to take up its position of rest. The writer finds that some of the most severe cases of photophobia, not due to inflammatory conditions, have been caused by latent heterophoria, particularly hyperphoria. Prolonged occlusion brings this latent condition to light. The use of the method of *prolonged occlusion* suggested the following conclusions: That the ordinary methods, at any rate when used only for the short periods possible during a consultation, may fail to reveal the kind and particularly the amount of error present. That while the method tends to show the true position of rest, the periods during which it is convenient to use it are insufficient to render the whole truth in the matter manifest. That while the constant use of prisms tends to bring out the heterophoria, prolonged occlusion accomplishes this with much greater rapidity and is free from the objections urged against prisms. That the total exophoria may greatly exceed the abduction as measured previous to occlusion and the same may be true of other forms of heterophoria.

Occlusion of the pupil. OCCLUSIO PUPILLÆ. See p. 6649, Vol. IX of this *Encyclopedia*.

Occlusive bandage. See p. 871, Vol. II of this *Encyclopedia*.

Occulting eyepiece. An eyepiece by means of which the field of view can be limited as desired.

Occupational diseases and injuries of the eye. This subject is outlined and to some extent discussed under such captions as **Injuries of the eye**; also, under *Industrial accidents* in **Blindness, Prevention of,** p. 1160, Vol. II of this *Encyclopedia*. It is also considered under **Conservation of vision,** p. 3251, Vol. V, and in the sections **Legal relations of ophthalmology** and **Nystagmus, Miner's.**

In this connection, Shanklin (*Jour. Ind. State Med. Assocn.*, April 15, 1914) points out the beneficial results following primary investigations of so-called industrial blindness, and the work of committees, appointed

from the American Medical Association and the various state medical societies, for the conservation of vision. Statistics from nine plants of the American Steel Foundries Co. show a reduction of 80 per cent. in the number of eye injuries, in less than three years. Six months after the inauguration of goggles for the protection of eyes, forty-eight pairs with one or both lenses broken, due to flying particles of steel, etc., were returned from one plant alone. From the nine plants of this company, in a like period, 287 pairs met with similar damage. It is noteworthy that during the past twenty-seven months but three men have lost an eye while at work in these plants, only one of whom was wearing his goggles at the time of the accident. The author's investigations have led him to the following conclusions: The safety first movement is successful in so far as related to eye injuries, at least. The large employers of labor are giving more and more attention to the physical care of their employes. There should be coöperation between oculists and the men in charge of safety departments. Publicity should be given the fact that even slight injuries of the eye may prove serious, and should have immediate and competent attention. The "storeroom expert" is a menace to the eyesight of the workmen he attempts to treat. Likewise the handy man in the mill. Eye surgeons should be regularly appointed by all the larger mills and factories, and in the railroad centers.

Edgar Collins (*Ophthalmoscope*, Oct., 1915) has also added to our knowledge of occupational eye injuries. He believes they may be grouped in classes which differ, not only in their origin, but also in prevention and treatment: 1. Injuries arising from direct traumatism, such as from flying fragments of stone or metal. Injuries in this group, since they occur at a definite moment of time, are legal "accidents." 2. Injuries due to the presence of foreign matter, often in the form of dust particles, injurious on account of its chemical composition. Such injuries may occur at a definite moment, due to a definite particle, or may be the result of prolonged exposure; and they occur from exposure to dust of pitch, lime, cement or to splashes of acid or alkalin fluids. 3. Injuries following upon exposure to intense heat and light. These injuries, which can seldom be considered legal accidents, require subdivision into (a) acute; e. g., conjunctivitis caused by exposure to the electric arc in the process of welding metals; and (b) chronic; e. g., posterior cortical cataract seen in glass workers exposed for years to heat and light from molten glass.

The percentage of all accidents due to eye injuries is slightly over five per cent., and in 1913 between seventeen and eighteen thousand eye injuries occurred among males employed in mines, quarries, fac-

tories and workshops. Granite workers show a special liability to eye injury, owing to the hardness of the stone and the use of pneumatic tools. Of seventeen hundred granite cutters employed in Aberdeen, statistics show that one out of every two require medical assistance for eye injuries annually; but the necessary protection seems largely absent.

Occupations for the blind. See major heading **Institutions and occupations for the blind.**

Ocellus. Eye spot. Eye speck. See **Comparative ophthalmology.**

The simple eye of many echinoderms, spiders, crustaceans, molluscs, etc.; a visual organ in which the sensory nerve-end cells are segregated into definite groups called retinulæ, a group of retinulæ being again characterized by possessing a single dioptric apparatus in common.

Ocherous. Ochery, Ochraceous. Of a brownish-yellow color.

Ochroleucous. Of a yellowish-white color.

Ochronosis. Ocronosus. Any disease accompanied by yellow discoloration; especially by yellow-brown pigmentation of cartilage, tendons or capsular ligaments. Discolorations of the eye and its adnexa occasionally occur in this affection. Schultz-Zehden (*Ophthalmic Year-Book*, p. 69, 1909) has reported a case in which there was a spot on the exposed sclera each side of the cornea in both eyes.

Ochsenauge. (G.) Buphthalmos.

Ockel, Peter von. A Russian physician, who paid considerable attention to diseases of the eye. Born at Sahten (Kurland), Russia, May 4 (15), 1780, he studied medicine at Königsberg, St. Petersburg, Halle, Jena, and Vienna, and received the degree of M. D. at Königsberg in 1806. He practised then for a long time at Mitau, dying Mar. 19, 1858.

Ockel's only ophthalmologic writing was his graduation dissertation, entitled "De Tumoribus in Cornea et Sclerotica Prominentibus."—(T. H. S.)

Octagon. Octangle. A figure of eight sides and angles.

Octant. The eighth part of a circle; an instrument on the principle of the sextant, having a graduated arc of 45°.

Ocular. Of, pertaining to, or depending on, the eye; visual; the eye-piece of any optical instrument.

Ocular aberration. See p. 7349, Vol. X, of this *Encyclopedia.*

Ocular anaphylaxis. See p. 339, Vol. I; also, under **Allergy,** p. 240, Vol. I, of this *Encyclopedia.*

See, in this connection, the sub-section on *Immunity*, p. 857, Vol. II.

Ocular, Campani's. See p. 1369, Vol. II, of this *Encyclopedia.*

Ocular compression. See **Oculocardiac reflex.**

Ocular conjunctiva. Conjunctiva covering the eyeball proper.

Ocular conjunctivitis. Conjunctivitis confined to the conjunctiva, covering the eyeball.

Ocular cup. The secondary optic vesicle of the embryo.

Ocular gymnastics. Gymnastics applied to the ocular muscles, e. g., by means of prisms.

Ocular hygiene. See **Hygiene of the eye.**

Oculariarius. In the ancient Graeco-Roman world, a person who made, or kept for sale, artificial eyes. These eyes, however, were not employed like our artificial eyes today, but were used in the heads of statues only. They were made of glass, silver, and, sometimes, precious stones. Hence the allusion in the well known passage of Elizabeth Barrett Browning's: "Shining eyes, like antique jewels set in Parian statue-stone." Such eyes formed, of course, a very early stage in the development of the *prothesis oculi.* The "oculariarius" should not be confounded with the "ocularious," or oculist—a physician who devoted himself chiefly or solely to the treatment of the eyes.—(T. H. S.)

Ocular jurisprudence. See **Legal relations of ophthalmology.**

Ocularly. By means of sight.

Ocular muscles. See **Muscles, Ocular.**

Ocular muscles, Injuries of the. See **Military surgery of the eye**; as well as **Muscles, Injuries of the extra-ocular,** p. 7882, Vol. X, of this *Encyclopedia.*

Ocular parasites. See the major heading, **Parasites, Ocular,** as well as such individual captions as **Cysticercus cellulosæ,** p. 3661, Vol. V; **Filaria,** p. 5195, Vol. VII; **Hookworm disease,** p. 6001, Vol. VIII, and p. 487, Vol. I, of this *Encyclopedia.*

Ocular, Ramsden's. A microscopic eye-piece made of two plano-convex lenses with the convexities turned toward each other.

Ocular spectrum. An after-image.

Oculi marmarygodes. See **Metamorphopsia,** p. 7663, Vol. X, of this *Encyclopedia.*

Oculin. A preparation of the hyaloid membrane and ciliary body of the eyes of oxen, said to be useful in eye affections, especially of the retina.

Oculi nocturni. Owl's eyes; supposed to be gray or blue eyes.

Oculist. A person principally engaged in the study and the treatment of diseases of the eye. This word has been generally abandoned in favor of *ophthalmologist.* although a distinction is sometimes made between them.

Oculocardiac reflex. EYEBALL HEART REFLEX. This reaction was first described by Aschner (*Wien. Klin. Wochenschr.*, XXI, p. 1529, 1908) and is sometimes spoken of as the Aschner reflex.

The oculocardiac reflex is a change in the heart's rate or rhythm following pressure on one or both eyeballs. The path of the reflex is generally considered to be along the fifth cranial nerve, the medulla and the vagus, or more rarely the sympathetic nerves. Usually slowing of the pulse rate results. This is probably due to inhibitory stimulation along the vagus nerve, and individuals showing this slowing are spoken of as vagotonics. Rarely there is an increase in the pulse rate. It is believed that in these cases the impulse passes along the sympathetic. Such persons are described as sympathicotonics. It is generally considered that in normal persons the cardiac rate is slowed from four to ten beats a minute. The diagnostic value of this reflex is not as yet definitely determined. There is some evidence to show that this sign may enable one to differentiate between disease of the heart muscle and disease of the cardiac nervous mechanism.

Loeper and Weill (*Ophthalmic Year-Book*, p. 28, 1914) have found *ocular compression* of value in controlling hiccough, persistent yawning, or spasmodic sneezing. See, also, p. 4888, Vol. VII, of this *Encyclopedia*.

Petzetakis (*Journ. Am. Med. Assocn.*, p. 664, Feb., 1917) reports that in six persons with myxedema of varying degrees of intensity the reflex phenomena from pressure on the eyeball were enormously intensified over what is observed in normal persons. The hypothyroidism leaves the sympathetic without the normal stimulation from the thyroid. As a consequence, the antagonist nervous system gets the upper hand, and vagotony results. He has induced a similar condition in dogs by nerve sections. Under thyroid treatment in one of his cases the lost balance was restored, and the oculocardiac reflex after a fortnight was about the same as in normal conditions. In two of the cases even light pressure on the eye for only two or three seconds arrested the heart's action for seven, eight, ten and fifteen seconds. Not a sound could be heard from the heart during this interval, even on auscultation. The young man in one case grew pale, stopped breathing and lost consciousness but the pulse gradually resumed its course, and became quite normal by the end of the second minute. It was the general impression that if the compression had been kept up a few seconds longer the syncope would have been definite. In this case, under thyroid treatment compression of the eyeball no longer induced syncope; it merely retarded the pulse to 20 or 25 beats per minute.

E. Murray Auer (*Journ. Am. Med. Assocn.*, p. 902, Mar. 24, 1917)

concludes, regarding the value of this sign in syphilis of the central nervous system, that abolition of the oculocardiac reflex is among the earliest signs of syphilitic disease of the central nervous system and one of easy diagnostic practicability to the general practitioner. The oculocardiac reflex was abolished on the side exhibiting the hemianalgesia with preserved tactile sensation in the case presenting the Millard-Gubler syndrome. In only one case of well marked tabes with cervical involvement in which pressure on the eyeball and testes was not painful was there evidence of diminished or disturbed superficial sensation other than in the case mentioned above. In 52 per cent. of the cases studied, the pulse rate ranged from 82 to 112, and the increased rate occurred chiefly among the well marked paretics. In third nerve palsy, the ptosis can sometimes be overcome by the patient reinforcing the ptotic lid by forcibly holding the lids of the sound eye closed. During the paroxysms of spasmodic weeping, occurring in pseudobulbar palsy, the radial pulse is practically imperceptible at the wrist, showing a reflex inhibition of the heart beat.

Oculometroscope. An instrument for performing retinoscopy in which the trial-lenses are rotated before the eyes without effort on the part of the examiner.

Oculomotorius. The oculomotor or third nerve.

Oculomotoriuslähmung. (G.) Paresis of the third nerve.

Oculomuscularis. Connected with the muscles of the eye.

Oculomuscularis communins. Oculo-motor nerve.

Oculomuscularis externus. Abducens nerve.

Oculomuscularis internus. OCULOMUSCULARIS SUPERIOR. Trochlear nerve.

Oculonasal. Distributed or pertaining to the eye and the nose.

Oculopupillary. Pertaining to the pupil of the eye.

Oculozygomatic. Pertaining to the region of the eye and to the zygomatic arch.

Oculus. (L.) See **Eye**; as well as **Eyeball.**

Oculus bovinus. OCULUS BOVIS. OCULUS BUBULUS. Buphthalmos; also hydrophthalmia.

Oculus cæsius. Glaucoma.

Oculus duplex. See **Binoculus,** p. 977, Vol. II, of this *Encyclopedia.*

Oculus elephantinus. Hydrophthalmia.

Oculus lacrimans. See **Epiphora,** p. 4492, Vol. VI, of this *Encyclopedia.*

Oculus leporinus. (L.) Hare's eye; lagophthalmos; see p. 6992, Vol. IX of this *Encyclopedia.*

Oculus purulentus. Hypopyon.

Oculus sinister. (L.) The left eye; often abbreviated to O. S.

O.D. Abbreviation for *oculus dexter*, right eye.

Odhelius, Johan Lorens. A celebrated Swedish physician and ophthalmologist. Born in Strengnäs, he studied his profession in Upsala, served for a time in the Swedish army in a medical capacity, and in 1760 received his medical degree. In 1752 he was made a Fellow of the College of Medicine, and for fifty years was physician to the Seraphim Hospital. He died in 1816.

Among his numerous writings, the only one possessed of ophthalmologic interest was "Anmärkinngar vid Staroperation och om den Sjukes Skötsel Efteròt" (Stockholm, 1775).—(T. H. S.)

Odontology, Ophthalmic relations of. See **Teeth**; and **Dental amblyopia**; as well as **Dentists, Amblyopia among**.

Œdema. Edema. This term is applied to the swelling occasioned by the effusion or infiltration of serum into cellular or areolar structures, especially into the subcutaneous cellular tissue. Œdema is not a disease, but a symptom, generally of cardiac or renal disease, and is often a symptom indicating great danger to life. See the captions on pp. 4154-6 of this *Encyclopedia*.

Oeffnungswinkel. (G.) Angle of aperture.

Oeil. (F.) The eye.

Oeil de loup. (F.) "Wolf's eye." A name given by Ambroise Paré to that condition of the eye in which the humors and tunics are black or pigmented.

Oeil de mauvais garçon. (F.) Same as oeil de loup.

Oenanthe crocata. Water hemlock. Holmes reports this as the most poisonous and dangerous of all native English plants. The symptoms of poisoning are very similar to those caused by *cicuta*, and the active constituent is very likely identical. The plant produces a fascicle of fleshly thickened roots very much like those of *cicuta,* although somewhat more slender and more tapering, but it contains a similar yellow, resinous, acrid poisonous juice. The root of this poisonous plant has often poisoned both children and adults. It produces convulsions and other psychic disturbances, followed or accompanied by dilatation of the pupil and scleral injection.

Oestrus ovis. A bot-fly that infests sheep and other four-footed animals. The parasite rarely attacks man and still rarely the human eye. However there are several recorded instances in which the ocular structures of man have been invaded. According to the *Ophthalmic Year-Book*, p. 416, 1914, cases have been reported in Sicily.

This type of larva is more common in mountainous regions. The conjunctivitis lasts from three to ten days and heals spontaneously. The Russian type (*Rhinoestrus purpureus*) is more dangerous, since this tends to burrow into the depth of the eye and eventually to destroy

the organ. It is more apt to attack the human eye. It is quite possible that a careful study of conjunctivitis occurring during hot weather in these countries would more frequently reveal the presence of larvæ in the human eye.

O'Ferral (or **Ferral**), **Joseph.** A celebrated Irish surgeon, re-inventor of enucleation of the eyeball, and re-describer of Tenon's capsule. Born in 1798 or '99, he studied with Carmichael, and in 1823 became an F. R. C. S. I. Settling in Dublin, he was soon appointed surgeon-in-chief and professor of clinical surgery at St. Vincent's Hospital, as well as vice-president of the Pathological Society. Later he became a Fellow of the Royal Academy of Ireland. He died Dec. 23, 1868.

The article in which O'Ferral re-described (but very much better than had been done by Tenon) the structure known today as Tenon's capsule, as well as the procedure now called enucleation, appeared in the *Dublin Journal of Medical Science*, p. 329, July 1, 1841.—(T. H. S.)

Office equipment. Every ophthalmic surgeon will have his own favorite furnishings for his private consulting room, laboratory, etc., and with the exception of the most general hints a description of what might be termed an average or ideal office equipment is in vain. The reader contemplating the furnishing of an office should visit and inspect the offices of his colleagues and should, in this connection, consult such headings in this *Encyclopedia* as **Hospitals, Ophthalmic,** p. 6025, Vol VIII; **Examination of the eye,** p. 4565, Vol. VI; **Charts,** p. 2007-23, Vol. III, etc.

Among the effective articles of equipment suited to the ophthalmologist's consulting rooms are the operating table described by L. W. Dean (*Journ. Am. Med. Assocn.*, Sept. 30, 1911) and those described as the "white line" in the catalogues of the Scanlon-Morris Co., Madison, Wis. Of course there are many others equally good.

Cooperation and business methods in office practice. An interesting and practical paper on this important subject is contributed by Linn Emerson (*Annals of Ophthal.*, Vol. XXV, No. 1, January, 1916). He states that the average income of the physicians of the United States is said to be less than one thousand dollars per year. Emerson, however, estimates that probably not more than five and twenty per cent. are fitted to practise the healing art, and expresses the hope that the higher standards now in force will result in fewer doctors, greater efficiency, and larger incomes.

He laments the absence of all attempt on the part of most medical men, either to systematize their practice, or to bring ordinary business methods to their assistance. He says that the average graduate in medicine has no idea either of business methods or of office routine;

he begins wrong, his business methods do not improve as his practice increases, and his affairs consequently pass into a state of chronic disorder, bad for his temper, his nerves, and his health.

The writer sets forth the methods which he has adopted as a result of fifteen years' experience. The whole tone of the article is fair, kindly, and honorable, whilst at no time does it lose the practical touch. It is an admirable refutation of the widely prevalent belief among medical men that the introduction of business methods into their work opens the door wide for the entry of a spirit of commercialism. The paper is studded with gems of advice, amongst the most delightful of which is that on the management of a fractious waiting patient by a tactful nurse. Two things must be most carefully avoided: first, any appearance of hurry; and, secondly, any failure to give the patient a full and careful examination. An obvious point made by Emerson is that the employment of a cycloplegic on Saturday or Sunday (he works Sundays) often spares a patient loss of time from business.

The spirit of the paper is shown in the brief concluding sentences, "Make no promises; be honest; never worry; do your best—angels can do no better." In discussing this paper (which should be read in full) W. A. Sedwick thought the idea of two men being associated together an excellent one. It is desirable for each man to take his own histories. It is advisable to have the light fall on the patient's face so that you can study the character of the patient. Saving of time is a good thing; but it is not well to be in too big a hurry. A word to the patient on things not directly connected with his case may be of advantage at times, as a means of getting his confidence. It is a good plan to take the vision before touching the eye, because people who have not known that one eye was defective are apt to blame the doctor. Sedwick thought it desirable to make out one's own bills, even if one must give a little time to it. The patient may wait longer if the bill is in the handwriting of an assistant than if in the doctor's own handwriting. If the patient is prepared to pay cash, Sedwick charges a lower amount for cash than if the account is placed on the books. He collects a good many bills by going to the bank and paying ten cents for a draft on the patient. He has taken the clock out of his reception room.

Oftalmite artritica. (It.) Gouty or rheumatic ophthalmia.

Oftalmite dei neonati. (It.) Ophthalmia neonatorum.

Ogilvie, Mrs. Margaret. A well known benefactor of ophthalmic institutions. The mother of Mr. F. M. Ogilvie, surgeon to the Oxford Eye Hospital, she gave large sums at different times to that institution, and, on one occasion, presented £5,000 to Oxford University for the estab-

lishment of a readership in ophthalmology. This readership is now known as Mrs. Margaret Ogilvie's Readership. Though not an ophthalmologist, or even a physician, the interest which was taken by this most estimable lady in ophthalmologic matters generally, should cause her to be remembered by the brotherhood. She died Apr. 2, 1908.—(T. H. S.)

Oguchi's disease. A name applied by Kusama to a form of *family retinal degeneration.* See **Familial affections of the eye.**

O'Halloran, Sylvester. A celebrated Irish surgeon, who devoted the most of his time and energies to ophthalmology. Born at Limerick, Ireland, he studied in Paris, London and Leyden. Returning to Limerick, he founded there an Eye Infirmary, was made in 1786 Honorary Fellow of the Royal College of Surgeons, and died in 1807.

His most important ophthalmologic writings were: 1. A New Treatise on the Glaucoma, or Cataract. (Dublin, 1750; 1753.) 2. A Critical Analysis of the New Operation for a Cataract. (*Trans. Irish Acad.,* 1755.—(T. H. S.)

Ohlemann's test for simulated blindness. See p. 1185, Vol. II, of this *Encyclopedia.*

Ohm, Georg Simon, (1787-1854). This German physicist was born at Erlangen, became director of the polytechnic school at Nuremberg, and in 1849 was made professor at Munich. He is chiefly known by the law which bears his name and by the *ohm,* a measure of electric resistance.

Ohmmeter. This device is a galvanometer, having a dial or scale graduated to ohms and fractions of ohms, for directly measuring the resistance of electric circuits.

Oidiumalbicans. Saccharomyces albicans. A fungus that produces thrush. It may, as a rare occurrence, attack the conjunctiva. In the case described by Pichler (*Beiträge zur Augenheilkunde,* part 24), a four months old child was attacked in both eyes by diphtheroid disease, with marked swelling of the lids and a profuse discharge. This was followed by corneal ulcer which eventually healed, with large corneal scars and staphyloma. A bacteriologic examination showed the presence of *saccharomyces albicans,* which the writer regarded as the cause of the disease. In another case reported by Larionow (*Jahresber. f. Ophthalmol.,* p. 330, 1886) this organism was found on the conjunctiva as primary infection, followed by the same deposit in the mouth and throat. In the eye attacked the cornea was involved, followed by ulceration and corneal opacities.

Oigopsid. (Obs.) Having the cornea of the eye "open"; opposed to *myopsid.*

Oil-beetle. See **Meloë.**

Oil, Cod liver. See **Cod liver oil,** p. 2313, Vol. IV, of this *Encyclopedia.*

Oil immersion. In microscopy, homogeneous immersion by means of (usually cedar) oil.

Oil of arachis. OLEUM ARACHIS. A fixed oil expressed from the seeds of *Arachis hypogaa,* the earth-nut, ground-nut or pea-nut. It closely resembles olive oil and is used, like it, in ophthalmology as a vehicle.

Oil of egg yolk. A fatty oil obtained by expression from the yolks of fresh eggs. Its chief ophthalmic use is as a popular remedy, abroad, for the removal of corneal opacities. See, also, **Egg, The, in ophthalmology,** p. 4162, Vol. VI, of this *Encyclopedia.*

Oil of juniper. See **Cade, Oil of,** p. 1353, Vol II, of this *Encyclopedia.*

Oil of mirbane. See **Nitrobenzol.**

Oil of turpentine. See **Turpentine.**

Oil, Olive. See **Olive oil.**

Oil, Sweet. See **Olive oil.**

Ointment, Blue. See **Blue ointment,** p. 1236, Vol II, of this *Encyclopedia.*

Ointment, Brooke's. An ointment for the treatment of tubercular disease of the palpebral skin, or lupus. See **Brooke's ointment,** p. 1313, Vol. II of this *Encyclopedia.*

Ointment, Brown. A name given by the Editor of this *Encyclopedia* to the dilute citrine ointment of the B. P. (*ungt. hydrarg. nitratis,* U. S. P.) when prepared with cod-liver oil instead of neat's-foot oil of the British or the lard of our own pharmacopeia. See p. 1316, Vol. II of this *Encyclopedia.*

Ointment, Diachylon. See **Diachylon ointment,** p. 3934, Vol. V of this *Encyclopedia.*

Ointment, Gray. See **Mercurial ointment.**

Ointment, Hebre's lead. See **Diachylon ointment.**

Ointment, MacNab's. An antiseptic remedy, especially employed in corneal ulcer, with the following formula: Hydrarg. bichlor., gr. ss; Iodoform, gr. xj; Atropine (alk.), gr. ij to viij; Vaseline, ℥i.

Ointment, Mercurial. See **Mercurial ointment,** p. 7646, Vol. X of this *Encyclopedia.*

Ointment of benzoin. See **Benzoated lard,** p. 933, Vol. II of this *Encyclopedia.*

Ointment of mercury. See **Mercurial ointment.**

Ointment, Pagenstecher's. Yellow oxide of mercury ointment.

Ointment, Silcox's. See **Silcox's ointment.**

Ointment, Simple. See **Unguentum simplex.**

Ointments. UNGUENTA. SALVES. UNGUENTS. These are fatty sub-

stances intended to be applied to the body surface by rubbing in, and having the consistence of butter. The material employed as a basis for the ointment varies considerably, and as a rule their activity and action are entirely due to the substance incorporated with the basis. The basis for most ophthalmic ointments may be lard, benzoinated lard, simple ointment, hydrous wool-fat (lanolin), ointment of rose-water (cold cream), petrogen, vasogen, various paraffins, hard petrolatum, glycerite of starch, boroglycerin or similar agents. Ointments should be perfectly smooth; that is, they should not contain any undissolved, hard, or gritty particles. When it is desired to incorporate into an ointment a substance which is insoluble in the basis, it is often necessary to use a small quantity of alcohol, water, or glycerin as a solvent before mixing with the ointment-base. Thus in making an ointment containing resorcin the latter should first be rubbed well with a little alcohol, water, or glycerin before it is mixed with the basis: iodine may be readily dissolved by adding to it a small quantity of potassium iodide, then a few drops of water, and so on.

A novel ointment and lotion diluter has been suggested by Charles Wray (*Ophthalmoscope*, Sept., 1908) for the accurate and aseptic reduction of the strength of salves and collyria. It consists of a hollow cylinder (open at both ends and marked off into equal parts, 1, 2, 3, 4, etc.) in which works an accurately fitted solid glass piston. To dilute an ointment with vaseline—to, say, one-fourth—insert the diluter into the ointment and draw up the piston until the ointment reaches the line marked 1. Then remove the instrument and cleanse the end with sterilized wool; insert it into the vaseline, drawing up the piston until the mixture reaches 4: after which the contents are to be pushed out into the lid of the ointment pot and mixed well together by means of the glass piston. The stronger dilutions should be made first and the weaker ones last, on the principle of diluting what has already been diluted.

Ointment, White's. See **Bichlorid-vaselin,** p. 949, Vol. II of this *Encyclopedia,* as well as **White's ointment.**

Okola eye remedy. A quack mixture for a time popular in America, finally suppressed by a "fraud order" from the U. S. Post Office Department.

Oldham, Charles James. A well known ophthalmologist of Hove, England. Born in 1846, he was once vice-president of the Ophthalmological Society of the United Kingdom, and for a long time surgeon to the Sussex Eye Hospital. He wrote almost nothing, but was a good operator. He was fond of music and made a collection of valuable musical instruments, among which were four Stradivarii. At the

time of his death he was president of the Brighton Sacred Harmonic Society. He died at his home in Hove, Sussex, Jan. 24, 1907, aged 62, leaving an estate of the gross value of nearly £78,000.—(T. H. S.)

Oleo-balsamic mixture. This preparation, official in the German *Pharmacopeia* (q. v.), is miscible in water. Either alone or as an adjuvat it makes soothing collyria in hyperemia of the conjunctiva and in the milder forms of conjunctivitis. Ohlemann, for this purpose advises: Mist. oleo-balsamicæ, 1:5 (gr. xxiii); Sodii salicylatis, 3.0 (gr. xlvi); Aquæ dest., 150.0 (℥ iv ʒvi).

Oleogen. A clear, yellow, oily ointment-base, containing oleic acid and yellow petroleum oil, with a proportion of ammonia. Sp. gr. 0.91. It is miscible with chloroform in all proportions. This mixture of oleic acid and petroleum oil is not subjected to the action of oxygen, and so differs from the patented vasogen.

Like vasogen and petrogen there are marketed a number of useful compounds with oleogen. Of interest to the ophthalmologist is oleogen ichthyol—a 10 per cent. mixture; oleogen iodi—a 5 and 10 per cent. iodine mixture. These liquid, oleogen compounds are rapidly absorbed when applied by inunction to the skin or mucous membrane. They are useful in chronic conjunctivitis, blepharitis and corneal opacities, especially when applied by means of massage.

Oleum amygdalæ expressum. See **Almonds, Sweet oil of,** p. 248, Vol. I of this *Encyclopedia.*

Oleum cadini. See **Cade, Oil of,** p. 1353, Vol. II of this *Encyclopedia.*

Oleum cajeputi. This agent is a volatile oil obtained from the fresh leaves of *Melaleuca leucadendron.* It is a thin, colorless, or greenish liquid, quite poisonous, and given in one to three drop doses for asthma, etc. According to Lewin and Guillery (*Die Wirkungen von Giften auf das Auge*, Vol. I, p. 478), it is a miotic and when rubbed into the eyelids is capable of contracting the pupil previously dilated by the ingestion of hyoscyamus.

Oleum eucalypti. The common variety of this agent is a volatile oil obtained from the fresh leaves of *Eucalyptus globulus.* It is a colorless, yellowish liquid, containing chiefly eucalyptol. The ordinary dose is from 5 to 15 minims, and it is supposed to be of value in various fevers and is used by inhalation in asthma. The oil of eucalyptus is a deadly poison, producing contraction of the pupil and loss of its reaction before death sets in. Wood (*Br. Med. Journ.*, Vol. I, p. 194, 1900) relates a case of poisoning in a three year old child who swallowed two or three teaspoonfuls of the oil. In four hours there was complete stupor, lack of the conjunctival reflex, marked contraction

of both pupils and absence of light reaction. In eight hours recovery occurred.

Oleum fagi. See **Beech, Oil of,** p. 922, Vol. II of this *Encyclopedia.*

Oleum jecoris aselli. See **Cod liver oil,** p. 2313, Vol. IV of this *Encyclopedia.*

Oleum morrhuæ. See **Cod liver oil.**

Oleum olivæ. See **Olive oil.**

Oleum ricini. See **Castor oil,** p. 1436, Vol. II of this *Encyclopedia.*

Oleum theobromæ. See **Cacao,** p. 1350, Vol. II of this *Encyclopedia.*

Oligemia. Hyphemia. Ecchymosis, especially of the conjunctiva. An old term for an extravasation of blood into the anterior chamber of the eye.

Oligoblennia. An ancient name for defective secretion of mucus.

Oligoöphthalmos. The apparently shrunken eye, such as one sees in myxedema. Jacobson (*Medical Times,* July, 1916) prefers the term "hypothyroidic eye" to express this condition.

Olio di ricino. (It.) Castor oil.

Olive oil. Oleum olivæ. Sweet oil. The fixed oil expressed from ripe fruit of *Olea europæa.* It is a pale, yellow, oily liquid with a neutral reaction, a bland taste and a faint, agreeable odor. Only the purest oil should be used in pharmacy.

Although this oil is among the commonest oleaginous remedies we have and has long been used in medicine it is not much prescribed in ophthalmic surgery. As an oleate we find it in "cold cream" and it is recommended as a solvent for atropia, eserin and other alkaloids, although it is questionable whether almond oil or the more viscid castor oil may not be its superior for that purpose. It makes a good menstrum for some tar ointments and may be used as an antidote (applied with a brush) to strong alkalies and lime in burns of the eye from these escharotics.

Oliver, Charles Augustus. A famous Philadelphia ophthalmologist, one of the authors of Norris and Oliver's "*Text-Book of Ophthalmology*" and one of the editors of Norris and Oliver's "*System of Diseases of the Eye.*" Born at Cincinnati, Ohio, Dec. 14, 1853, a son of Dr. George Powell Oliver (the founder and first president of the Medico-Chirurgical College of Philadelphia) he removed in very early childhood with his parents to Philadelphia. He received the degrees of A. B. and A. M. at the Philadelphia Central High School, and the degree of M. D. in 1876 from the University of Pennsylvania. Having served a year as resident physician in the Philadelphia Hospital, he was appointed clinical clerk to Dr. William F. Norris, professor of ophthalmology at the University of Pennsylvania. From 1890 until

his death he was attending surgeon and secretary to the surgical staff at the Wills Eye Hospital. In 1894 he was made ophthalmic surgeon to the Philadelphia Hospital. He was appointed associate clinical professor of ophthalmology in the Woman's Medical College in 1897, and full clinical professor in 1906. He was for a time consulting ophthalmologist to the Friends' Asylum for the Insane and to the State Hospital for the Chronic Insane of Pennsylvania. He was a member of fifty-six scientific societies in America, and of thirty-three

Charles Augustus Oliver.

abroad. He was a tireless worker, but, like many another gifted ophthalmologist, was early obliged to pay the penalty for overwork. Having acquired a chronic nephritis, with cardiac complications, he died suddenly from an attack of acute pulmonary edema, at his home in Philadelphia, April 8, 1911.

Dr. Oliver's books were left to Harvard University and to the University Club of Philadelphia. His pictures were bequeathed to Lafayette College, Easton, Pennsylvania. His estate, outside his books and pictures, consisted of only $15,000.00 for he had been very generous. Of this amount one third was given to the Wills Eye Hospital, another for the foundation of a prize in ophthalmology, while the remainder went to the College of Physicians of Philadelphia for the purchase of ophthalmologic journals.

Dr. Oliver's writings were very numerous. The journal articles

alone, inclusive of abstracts and reviews are said to amount to "several hundred." His most important literary services, however, in addition to those rendered in connection with the "*Text-Book*" and the "*System*," are these:

1. Translated and edited the English editions of Ohlemann's "*Ocular Therapeutics.*"

2. Translated and edited Baudry's "*Injuries to the Eye in their Medico-Legal Aspects.*"

3. Translated and edited Donders's "*Essay on the Nature and Consequences of Anomalies of Refraction.*"

4. "*Paracentesis, Keratotomy, Conjunctivoplasty, and Some Other Operations on the Eye.*"—(T. H. S.)

Olive tree. The various products of *Olea europaea* were employed by the ancient Greeks and Romans in the treatment of diseases of the eye. The resin, or "tears," was placed inside the conjunctival sac for various diseases of the cornea, and the juice was employed in a similar manner for phlyctenules, prolapse of the iris and staphyloma. The oil was abundantly employed as a menstruum for various ophthalmic medicaments, while the leaves and blossoms, well roasted, were employed as adjuvants in numerous ophthalmic prescriptions.—(T. H. S.)

-Oma. A Greek suffix or termination implying a morbid condition, especially a tumor, of the part indicated by the word to which it is attached.

Omar b. Junus al-Harrani. A distinguished Cordovan physician, chiefly remembered today because of the fact that, together with his brother Ahmad, he studied the diseases of the eye under Ibn Wasif at Bagdad for almost 22 years—941 to 963 A. D.—(T. H. S.)

Omatropina. (It.) Homatropin.

Omma. The same as ommatidium.

Ommatidium. Omma. One of the numerous segments of which the compound eye of a crustacean is made up. See **Comparative ophthalmology.**

Omnopon. Omnopon-scopolamin. Omnopon or pantopon is a 2 per cent. solution of the total alkaloids of opium; its average dose is 2/3 grain; and 1/150 grain of scopolamin is the amount usually given when the two are combined. Maitland Ramsay (*Lancet*, April 25, 1914) is enthusiastic concerning the quieting effects on the patient when the doses given above are administered hyperdermically in conjunction with local anesthesia for ophthalmic operations.

On the whole, omnopon acts best in elderly patients, and may be safely given in cases in which the administration of a general anes-

thetic might be attended by considerable anxiety and danger. The patient is prepared as for general anesthesia and 1½ hours before the operation the contents of a 1 c. c. sterile ampoule are injected into the muscles of the gluteal region; the patient is kept in bed until required in the operating room and rests quietly or sleeps during this period. During the operation he wakens when spoken to and is ready to assist the operator by voluntarily turning his eye in whatever direction may be necessary.

Ramsay has used omnopon-scopolamin as an adjuvant to local anesthesia in the following operations upon the eyeball and its appendages: Cataract extraction, iridectomy in iritis and in acute glaucoma, iridosclerectomy in chronic glaucoma, plastic operations on the eyelids, extirpation of the lachrymal sac, and enucleation of the globe. In these different operations omnopon-scopolamin acted least satisfactorily in extraction of senile cataract, because it made the patient so drowsy that the eyeball constantly tended to roll upward, and thereby hindered the delivery of the lens.

Omodei, Carlo Giuseppe Annibale. A well known Italian surgeon, ophthalmologist, and medical lexicographer. Born at Cilavegna, near Vigenano, Sardinia, on April 17, 1779, he received his medical degree at Pavia in 1800. After a scientific journey through Germany and Austria, he settled as surgeon at Milan. In 1804 he became Major Physician at the Milan Military Hospital, a position which he held for ten years. From 1817 till 1840, the year of his death, he edited the *Annali di Medicina.*

Omodei's only ophthalmic writing is entitled "*Cenni sull' Ottalmia Contagiosa d'Egitto e sulla Propagazione in Italia*" (Milan, 1816; Ger. trans. by Wolf, Frankfort a. M., 1820).—(T. H. S.)

Omphacium. This is the name employed by the elder Pliny to designate wine made from unripe grapes. Concerning the use of omphacium, Pliny (Book xxiii, chap. 4) has the following passage: ". . . it is very good, too, for the sight, for rough spots upon the eyelids [trachoma] ulcers at the corners of the eyes, films upon the eyes, . . ."—(T. H. S.)

Onanism. See **Masturbation,** p. 7615, Vol. X of this *Encyclopedia.*

Oncoma. An ancient name for a tumor.

Oncotomy. The opening of an abscess or tumor.

One-eyed. Uniocular. This subject of one-eyed persons has been referred to and discussed under various captions in this *Encyclopedia*, but especially under **Visual economics** and the **Legal relations of ophthalmology.** A. J. Ballantyne (*Ophthalmoscope*, p. 498, Aug., 1914) in discussing the paper of W. P. C. Zeeman (*Klin. Monatsbl. f.*

Augenheilk, Dec., 1912) points out that he attempts to throw light on the questions whether, during the first year or so after the loss of an eye there is any increase of the monocular power of depth-perception, and whether measurement of this power gives a guide to the assessment of compensation for injury. He shows that monocular and binocular vision differ both quantitatively and qualitatively. We have to take into account differences in light and dark adaptation, differences in central vision, differences in the power of fixation, and differences in the field of vision, as well as the more important differences in power of depth-perception.

In dark adaptation a surface looks brighter to two eyes than to one; that is to say, the threshold is lower for binocular than for monocular vision. It is a familiar fact that central visual acuity is often better when both eyes are employed than with one eye alone. The reason for this has not yet been clearly established. Two explanations are suggested.—The first is that if there is an uncorrected or incompletely corrected astigmatism, letters which are imperfect to one eye may be clear to the other, the two eyes thus supplementing each other and together producing a better result than could be obtained with either one alone. The other explanation depends on the assumption, which still needs proof, that fixation of an object is steadier and less difficult with two eyes than with one.

Coming to the differences in the depth-perception of the one-eyed and the two-eyed, the author first considers all the different factors which enter into the composition of this faculty, and reaches the conclusion that the one-eyed is at a disadvantage as compared with the two-eyed in the loss of the binocular parallax and of the information derived from convergence, and that he has to depend on the monocular parallax (involving movement of the head or of the object) and on information derived from shadows and other phenomena of less importance. It has been proved experimentally that the time required for the appreciation of the relative positions of two objects is much less in binocular than in monocular vision. The figures arrived at by Zeeman are 1/200 and 1/2 second respectively. Of course, all tests bearing on this point involve the fallacy that the intellectual capacity of the individual influences the results, but, as the author points out, the same influence comes into play in the restoration of a man's capacity for his work. Some of the author's conclusions are as follows.—Uniformity in the character of the work favors an early reacquisition of working capacity, and change of occupation is unfavorable in this respect. No method of measuring depth-perception can give conclusive proof of the working capacity of a one-eyed person. Prob-

ably with even the most complete adaptation to the new conditions, the one-eyed is slower at appreciating depth differences, and is more readily fatigued. At the same time Zeeman thinks that the increased effort demanded in these circumstances is not more than is possible to the average healthy man.

Onglet. (F.) Pterygium.

Onguent. (F.) An ointment. In the last edition of the Fr. *Codex* the term has been generally replaced by *pommade.*

Onguent ophthalmique. (F.) Unguentum zinci oxidi.

Onguent ophthalmique vert. (F.) UNGUENTUM OCULARE KLISERI. An ointment made of 8 parts of verdigris, 150 of tartar, 40 of camphor and 620 of lard.

Onice. (It.) Onyx.

Onion. *Allium cepa.* Onion juice, mixed with honey, was often employed in ancient Greco-Roman times as an instillation for incipient cataract and also for any and every affection of the cornea. An onion poultice was sometimes used for epiphora. The eating of onions was at first regarded as injurious to the eyes; later, however, as beneficial. —(T. H. S.)

Onyx. Corneal abscess. See p. 3331, Vol. V of this *Encyclopedia.*

Opacities, Corneal. See p. 3416, Vol. V of this *Encyclopedia.*

Opacities, Intraocular. See **Muscæ volitantes,** p. 7880, Vol. X of this *Encyclopedia;* also **Cataract, Incipient.**

Opacity balance. An optical instrument—the best known being that of Chapman-Jones—for determining the proportions of luminous rays in light pencils. See **Glass, Optical,** p. 5396, Vol. VII of this *Encyclopedia.*

Opacity, Band-like. See **Band-shaped keratitis,** p. 877, Vol. II of this *Encyclopedia.*

Opacity, Berlin's. An injury to the retina generally due to concussion. See **Berlin's opacity,** as well as p. 2517, Vol. IV of this *Encyclopedia.*

Opaloid. Semi-translucent.

Opaque colors. Colors which reflect, but do not transmit, light.

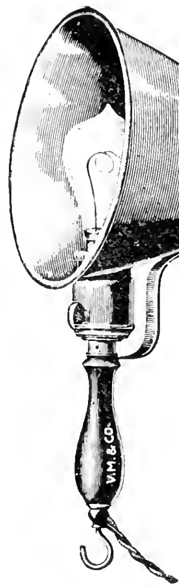
Opaque nerve-fibres. See **Nerve fibres, Opaque.**

Opeidoscope. An apparatus for studying the vibrations of the voice by means of light reflected from a mirror.

Open method in tenotomy. See **Muscles, Ocular,** under *Operations.*

Open treatment. See p. 161, Vol. I of this *Encyclopedia.*

Operating lamp. See **Lamps, Ophthalmic;** also p. 4602, Vol. VI of this *Encyclopedia.* Of the simpler, more recent and, it may be added, convenient forms of handlamp for operation in ophthalmic cases the parabolic form depicted here is to be recommended.



Portable Parabolic Reflector.

Operating mask. See p. 1628, Vol. III of this *Encyclopedia.*

Operating room. See **Hospitals, Ophthalmic,** p. 6025, Vol. VIII of this *Encyclopedia.*

Operating tables. See p. 1630, Vol. III, also p. 6049, Vol. VIII of this *Encyclopedia.*

Operation. Individual surgical procedures under this head have been mostly described and illustrated under such appropriate headings as **Bonnet's operation.** A few others, under such captions as **Operation, Donegana's,** follow in order. In addition, complete accounts of operative measures intended to relieve abnormal conditions are to be found under rubrics like **Cataract, Senile**; **Iridectomy**; **Enucleation and its substitutes,** etc.

In the succeeding **Operation** headings only those that are or have been intimately associated with the inventor, reporter or discoverer are given special mention.

Operation, Arlt-Jaesche. See **Arlt-Jaesche operation for trichiasis,** p. 589, Vol. I of this *Encyclopedia.*

Operation, Assalini's. See **Assalini's operation,** p. 647, Vol I of this *Encyclopedia.*

Operation, Bartisch's. See **Bartisch's enucleation operation,** p. 895, Vol. II of this *Encyclopedia.*

Operation, Benson's. See **Benson's operation for entropion,** p. 932, Vol. II of this *Encyclopedia.*

Operation, Bonnet's. See **Bonnet's operation,** p. 1248, Vol. II of this *Encyclopedia.*

Operation, Bonzel's. See **Bonzel's operation,** p. 1248, Vol. II of this *Encyclopedia.*

Operation, Bribosia's. See **Bribosia's operation,** p. 1292, Vol. II of this *Encyclopedia.*

Operation, Chibret's. The establishing of corneal drainage for glaucoma.

Operation, Cowell's. Paracentesis of the vitreous chamber, for glaucoma.

Operation, Critchett's. 1. For *cataract-extraction;* a slight modification of Graefe's incision. 2. For *evisceration* of the eyeball; a number of deep stitches are passed through the sclera before removing the staphyloma; after the evisceration they are brought together and tied. 3. For *iridodesis;* drawing of the iris through a corneal incision and its ligation with silk. The ligatured loop sloughs off.

Operation, Del Toro's. See **Del Toro's operation,** p. 3811, Vol. V of this *Encyclopedia.*

Operations, Desmarres'. See **Desmarres, Louis-Auguste,** p. 3852, Vol. V of this *Encyclopedia.*

Operation, Dianoux's. See **Dianoux's operation for entropion,** p. 3938, Vol. V of this *Encyclopedia.*

Operation, Dieffenbach's. See **Dieffenbach's (J. F.) operation,** p. 1069, Vol. II of this *Encyclopedia.*

Operation, Donegana's. See **Donegana's operation,** p. 4064, Vol. VI of this *Encyclopedia.*

Operations, Drausart's. 1. For *ptosis;* the occipito-frontalis muscle is brought to act on the lid through the medium of cicatricial bands, by means of threads, which are allowed to ulcerate their way through the tracks along which they were passed. 2. For *retinal detachment;* iridectomy, the recumbent position, a pressure-bandage, and subcutaneous injection of small doses of pilocarpin.

Operation, Equilibrating. Tenotomy on the direct antagonist of a paralyzed ocular muscle.

Operation, Hartley-Krause. The removal of the entire Gasserian ganglion and its roots for relief of facial neuralgia.

Operation, v. Hippel's. For transplantation of the cornea. See p. 3490, Vol. V of this *Encyclopedia.*

Operation, Hotz. See p. 4360, Vol. VI of this *Encyclopedia.*

Operation, Krönlein's. See **Krönlein's operation,** p. 6871, Vol IX of this *Encyclopedia.*

Operation, Motais'. For *ptosis:* a strip in the superior rectus is cut and pulled through a buttonhole in the tarsal cartilage and sutured to the upper lid.

Operation, Noyes'. For *blepharoplasty;* the formation of a bucco-temporal flap, sliding the whole cheek, with the shortened lid, inward and upward. For *entropion;* cure by a plastic operation. For *staphyloma;* incision of the limbus, followed by total avulsion of the iris. For *strabismus:* advancement of the elongated tendon.

Operation, Nuël's, for corneo-scleral rupture; the wound in the sclera is reopened by making a section with a knife, and the surrounding conjunctiva is drawn over the opening by means of a special suture.

Operation, Odhelius's, for iridotomy; the same as Reichenbach's operation.

Operation, Pagenstecher's. For *cataract-extraction;* extraction of the lens in the closed capsule; a scoop is inserted under the lens and gentle pressure is made on the cornea. For *entropion;* division of the external canthus; stretching of the horizontal wound to a vertical one, and suture of the opposed surfaces. For *obliteration of the lachrymal sac;* slitting of the canaliculi, and the introduction of zinc chlorid paste into the sac. For *pterygium;* separation from the cornea and sclerotic and turning back; the edges of the conjunctival wound are brought together with sutures. See the various appropriate headings.

Operation, Panas'. For ptosis; the tarsal portion of the lid is raised by sutures and the occipito-frontalis muscle is caused to assume, to a great extent, the function of the levator palpebræ.

Operation, Passavant's. For *synechia;* breaking up of the adhesions with forceps.

Operation, Pétrequin's. For symblepharon; gradual strangulation by means of a thread.

Operation, Physick's. For iridectomy; removal of a circular piece of the iris by a special cutting-forceps.

Operation, Platner's. For excision of the lachrymal sac; incision of the anterior wall, followed by removal of the sac-wall.

Operation, Pope's. For the formation of an *artificial pupil;* incision at the sclero-corneal margin, with excision of a portion of the iris without dividing the sphincter pupillæ. For *entropion;* extirpation of the tarsus. For *trichiasis;* similar to the Arlt-Jaesche operation.

Operation, Preparation for. Something is usually said on this subject as a preliminary to the discussion of each operation under its appro-

priate heading. A good general description of operative preparedness will be found on p. 1625, Vol. III of this *Encyclopedia.*

Operation, Rau's. For the formation of an artificial pupil; perforation of the sclera and iris with a narrow knife, followed by iridectomy.

Operation, Reichenbach's. For iridotomy; incision of the cornea and division of the iris from before backward.

Operation, Reverdin's. For *blepharoplasty;* removal of the cicatricial tissue, suturing of the lid to the opposite one in its normal position, and skin-grafting of the raw surface. For *skin-grafting;* a point of skin is raised on an ordinary sewing-needle, and shaved off with a scalpel or scissors; the graft is then transferred to the fresh surface next to the healthy granulations. For *symblepharon;* detachment of the lid and transplantation of a small flap from the cheek. See **Blepharoplasty.**

Operation, Richet's. For *ectropion;* the cicatrix (situated at the outer side of the lower lid) is excised, and, after the lids have been stitched together, the gap is filled, and the operation is completed by raising and transplanting two tongue-shaped flaps.

Operation, Richter's. 1. For *iridotomy;* the same as Reichenbach's operation. 2. For *stricture of the lachrymal duct;* incision of the sac and dilatation of the duct by means of catgut strings.

Operation, Robertson's. For conjunctival entropion; a modification of Snellen's operation, in which the threads are passed through the conjunctiva at the bottom of the fold, between its palpebral and outer portions.

Operation, Sabatier's. For iridectomy; excision through a corneal incision, as in cataract-extraction.

Operation, Saemisch. SAEMISCH SECTION. See p. 6838, Vol. V of this *Encyclopedia.*

Operation, Salzer's. Excision of the whole of the third division of the fifth nerve.

Operation, Scarpa's. For *iridodialysis;* a needle is plunged through the sclerotica, the point passed through the superior internal border of the iris from behind forward, and with a see-saw motion the iris is detached in one-third of its circumference. For *stricture of the lachrymal duct;* incision of the interior wall of the sac and the introduction of a leaden style into the duct.

Operation, Schmidt's. For iridodialysis; the same as Scarpa's operation.

Operation, Schueller's. For entropion; two elliptic skin-incisions are made, united at their ends, and the distal margins are sutured together, over the included portion of attached skin.

Operation, Schweigger's. For advancement of a rectus muscle; the muscle is transfixed by catgut sutures, a portion of the tendon is removed and the ends are approximated by passing the sutures that have been placed in the muscle. See **Muscles, Ocular.**

Operation, Sédillot's. For strabotomy; an incision is made over the body of the muscle; when the latter is completely exposed, the hook is inserted and division made with the scissors.

Operation, Serres'. 1. For blepharoplasty; the same as Knapp's operation. See p. 1081, Vol. II of this *Encyclopedia.*

Operation, Stellwag's. 1. *Canthoplasty;* an oblique blepharotomy or sphincterotomy. 2. For *cataract-extraction;* a corneal flap-extraction. 3. For *trichiasis;* re-attaching the raw surface of the tarsus to the ablated zone of hair-follicles, so that the border that bears the cilia looks upward and that which has the raw surface looks downward.

Operation, Story's. For entropion and trichiasis; the insertion of a piece of mucosa which entirely and permanently removes the cilia from contact with the cornea.

Operation, Streatfeild's. 1. For *atresia of the punctum lachrymale;* slitting of the canaliculus. 2. For *cataract-extraction;* it is made with a Sichel's knife without counter-puncture, the wound being enlarged by a sawing motion. 3. For *entropion;* removal of a wedge-shaped strip from the tarsal cartilage. 4. For *synechia;* the same as Passavant's operation, except that a cutting-hook is used in place of forceps.

Operation, Streatfeild-Snellen. For entropion; like Streatfeild's operation, except that the groove in the tarsus is made higher up.

Operation, Szokalski's. For pterygium; the growth is removed by means of a thread, armed with two needles, so that the growth is strangulated at each end and en masse between.

Operation, Szymanowski's. For ectropion. See pp. 1071, and 1076, Vol. II of this *Encyclopedia.*

Operation, Teale's. 1. For *cataract-extraction;* removal of a soft cataract by suction. 2. For *lachrymal stricture;* slitting of the lower canaliculus and introduction of different sized olive-pointed probes. 3. For *symblepharon;* two flaps of the bulbar conjunctiva are taken from either side, one of which is used for covering the inner surface of the lid, while the other serves as a covering for the eye.

Operation, Theobald's. For subconjunctival strabotomy; it is performed after Critchett's method, a "crochet-hook" being used instead of the ordinary blunt one, to prevent the tendon slipping off. See **Muscles, Ocular.**

Operation, Thread. An operation proposed by von Graefe, for regulating the position of the eyeball after tenotomy; the thread is

passed through the stump of the tendon and is fastened to the skin near the eye.

Operation, Travers'. For cataract-extraction; the capsule is divided and the lens is displaced into the anterior chamber; it is then removed through a small corneal incision.

Operation, Velpeau's. For iridotomy; a long double-edged knife transfixes the cornea, passes through the iris to the posterior chamber and back to the anterior chamber, through the cornea again, and a flap is cut; this leaves a triangular opening in the iris.

Operation, Villard's (Carron). 1. For *ectropion;* shortening of the skin of the lid in a transverse direction. 2. For *iridotomy;* the same as Maunoir's operation.

Operation, Waldau's. For cataract-extraction; this differs from the linear method of v. Graefe only in the smaller incision (less than ¼ of the circumference of the cornea) and in the use of a special scoop to remove the lens.

Operation, Walther's. For tarsorrhaphy; paring of the borders of the upper and lower lids adjoining the external angle and securing the denuded surfaces together.

Operation, Walton's. For lachrymal stricture; slitting of the upper canaliculus into the sac, and the introduction of pure silver pins.

Operation, Wardrop's. For entropion; ligation of a small portion of the skin by a suture passed beneath.

Operation, Warlomont's. 1. For *cataract-extraction;* a modification of the Graefe incision. 2. For *trichiasis;* the portion of lid in which the cilia are implanted is detached, shifted upward, and fixed upon the tarsus.

Operation, Watson's (Spencer). 1. For *entropion;* transplating a bridge of skin from the eyelid through to the conjunctival surface. 2. For *trichiasis:* the wound is covered by a pedunculated flap.

Operation, Weber's. 1. For *cataract-extraction;* the incision is made with a curved bistoury. 2. For *lachrymal stricture;* a modification of Bowman's operation; slitting of the upper canaliculus, subcutaneous division of the canthal ligament, and dilatation by a conic silver sound and elastic catgut bougies.

Operation, De Wecker's. 1. *Blepharoplasty;* a modification of Reverdin's operation; it consists in transplanting small pieces of epidermis covered with gold-beater's skin. 2. For *cataract-extraction;* a modification of the Graefe incision in cataract-extraction, and extraction without iridectomy. 3. For *corneal or lenticular opacities;* division of the sphincter of the iris by introducing forceps-scissors through the corneal incision. 4. For *evisceration;* a suture is run through the pre-

viously loosened conjunctival and subconjunctival tissue surrounding the cornea, and is carried entirely around by repeated punctures; the protrusion is then cut off and the two ends of continuous suture are drawn together, thus preventing the escape of the vitreous. 5. For *glaucoma;* trephining of the cornea. 6. For *iridotomy;* an incision is made with von Graefe's knife through the cornea and iris; the forceps-scissors is then introduced, and a V-shaped portion of iris is removed.

Operation, Wells'. For *blepharoplasty* of the upper lid; dissection of the cicatrix, replacement of the lid to its normal position, and transplantation of a flap from the temple. For *entropion;* splitting of the lid into anterior and posterior leaves, excision of a fold of skin, and removal of a wedge-shaped piece of the tarsus. For *strabotomy;* division of the tendon, subconjunctivally, close to its insertion.

Operation, Wenzel's. 1. For *cataract-extraction;* in cases of total posterior synechia, a curved incision is directed downward, passing through the iris, and opening the lens. 2. *Iridectomy;* the same as Velpeau's operation, except that the flap is removed.

Operation, Wickerkiewicz's. For scleritis; the removal by means of a small sharp spoon of the diseased tissue in stubborn cases.

Operation, Wilde's. For *staphyloma;* very similar to Critchett's operation, (q. v.). 2. For *trichiasis;* an incision is made to the roots of the inverted cilia followed by cauterization with silver nitrate and removal of the cilia.

Operation, Williams'. For lachrymal stricture; a modification of Walton's operation; dilatation by large silver probes.

Operation, Wolfe's. 1. For *ectropion;* transplantation of a flap from a distance, without a pedicle. 2. For *retinal detachment;* a vertical incision is made in the conjunctiva and subconjunctival tissue, and an oblique incision into the sclera, followed by gentle pressure and suture. 3. For *symblepharon;* transplantation of the conjunctiva of a rabbit after division of the adhesions of the lid.

Operative skill in ophthalmic surgery. This subject has been pretty thoroughly discussed by the present writer in a *System of Ophthalmic Operations*, Vol. I, p. 179, and it seems to him that there is very little stated there that he does not now indorse. He still believes that no field of operative work requires more qualifications on the part of the surgeon than ophthalmic operations. We may say, all other things being equal, that the one who has a special aptitude for, and love of, the work may be more successful than one who has no such natural tendencies, but, on the other hand, there are some natural qualifications which must be developed and others which must be acquired by any person who is to achieve the highest success as an ophthalmic operator.

To be a thorough surgeon, it is necessary, above everything else, to know well the organ on which one operates. A comprehensive knowledge of the anatomy and physiology of the eye is therefore indispensable, and without it the appearance and function of the eye are subject to serious and unnecessary impairment through the unskilled operative attention of a surgeon. The requisite knowledge of the anatomy and physiology of the eye cannot be acquired wholly through the perusal of text-books, but must be sought as well, in the study of the organ itself. This education is not complete until it includes thorough and painstaking dissections of the eye in the cadaver, and repeated observation and study of the normal eye in the living. It should also be supplemented by experimental study of animals' eyes and such vivisection as will aid in a better understanding of the various functions of the eye.

Aside from a thorough knowledge of the anatomy and physiology of the eye the skilled ophthalmic operator should possess suppleness of movement, delicacy of touch, quickness of perception and good judgment. These may be inherent qualifications, but they may be developed and improved by training and experience, and are affected by certain conditions and circumstances which must be considered in the development of an accomplished operator.

The *condition of the surgeon's health* may have an important bearing upon his operative success. No man who has an organic or functional affection of the nervous system should attempt ophthalmic surgery, and in fact any disease or condition which weakens the vitality and lowers the nervous tone has its detrimental effect upon the ophthalmic operator. For essentially similar reasons one who has been crippled in the fingers or eye, or deformed, or has function impaired from arthritis deformans, rheumatism, or from any other cause is not fitted for the best type of operative work. Good health and a sound body are essential to the success of the ophthalmic operator, and anything which detracts from this necessary condition impairs the chances of success. Thus the practice of some noted operators to avoid engaging in pastimes or occupations which will strain the muscles of the arms or bruise or scratch the fingers, or roughen the skin, and by so doing impair the muscular action and sensitiveness of touch so necessary in a skillful operator, is worthy of adoption by those who appreciate the value of physical fitness. It should be remembered, however, that appropriate gymnastics and exercises of any kind not violent, fortify the health, physical and moral, and augment the courage.

Care in diet also has its beneficial effect in keeping the health and

temperament at its best. No one whose temperament is marred by a diseased stomach due to injudicious eating or drinking can expect to do the best by a patient requiring the highest form of delicate skill, and no person whose nerve tone is lowered by the use of stimulants or narcotics is fitted to do the intricate surgery which an eye may require.

Good eyesight is absolutely essential to success as an ophthalmic operator, and one who is not emmetropic should wear the proper lenses to correct his error of refraction. It is also essential that the field of operation should be well illumined either by natural or artificial light.

Nervousness may be present in the best of operators, but it should be avoided by suitable training and habits lest the patient suffer from the effects of such a deplorable condition. Landolt says, "one need not tell us that he has seen good operators tremble. They were perhaps great oculists but certainly not perfect operators. Or, if they had been formerly, they had lost that quality with age.

Trembling may have other causes than senility. Very often it is of nervous origin. A certain restlessness and inquietude comes over some surgeons as soon as they are summoned to operate upon a patient, be he awake, asleep or even dead. Generally an active imagination plays an important part by bringing to the mind of the operator all the dangers that can possibly present themselves during and after operation. Sometimes it is not so much interest for the patient as ambition—the fear to excite the criticism of those around—which deprives the surgeon of the necessary composure. The poor unfortunate then finds himself in a predicament: the more he longs to shine the more he trembles, and the more he becomes demoralized."

Tobacco, alcohol, tea and coffee, often have power to influence in a most deplorable manner the hand of the operator.

Alcohol is especially apt to disturb the digestive tract and nervous system, while tobacco and strong coffee or tea, particularly if indulged in immediately preceding operative work, frequently produce a nervousness or inquietude of the surgeon which is detrimental to the best type of surgical work. Sobriety is therefore indispensable to the ophthalmic operator who desires to attain the highest degree of success.

The *amount and kind of rest* taken by the operator may have its effect upon the result of operative work. Long hours in the office, followed by long hours in social diversion and the consequent loss of sleep may seriously alter what otherwise would be a steady hand. The old adage, "all work and no play make Jack a dull boy," may in a measure be applied to the ophthalmic surgeon, for long periods of work without rest or recreation have a tendency to destroy the com-

posure of mind, steadiness of movement and cool judgment required of one who is called upon to operate upon an organ that is not only delicate and whose movements are so varied and multiple, but whose function may be destroyed so quickly by a false action which in any other branch of surgery would be considered insignificant.

But often the *uncertainty of the hand* is due simply to weakness of the arm. If the latter has not the force to sustain itself for quite a while immobile in one position it begins to tremble, and its movements, hardly perceptible at the shoulder, augment in a most dangerous manner at the extremities of the fingers. This condition may be overcome by judicious corporeal exercise. In fact, all which tends to fortify the health, physical and moral—all that which renders more vigorous the arm and strengthens the courage—can only profit the surgeon.

The selection of the *best time for performing* ophthalmic operations should be considered from the standpoint of the operator as well as the patient. Most men operate with steadier hand and better judgment early in the morning when fresh from a night's repose and muscles not tired nor nerves unstrung from the labors and vexations of a day's routine work. But the patient should also be considered, and oftentimes it is a matter of necessity to operate promptly, no matter what time of day. In the matter of cataract extraction it has been held by many experienced operators that the operation should be performed late in the afternoon or early in the evening, and for the reason that the smarting or pain which follows the procedure is over at about the time the patient would naturally go to sleep, and a night's sleep with its attending quiet may give the wound a chance to close. If operated in the morning the patient may be nervous and restless throughout the day, and the wound does not have a chance to close until later, thus adding to the dangers of complication.

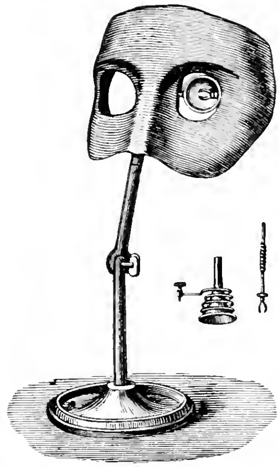
If especially delicate or intricate operations are to be performed during the latter part of the day or in the evening, it is advisable that the surgeon have a short period of rest immediately preceding his task, with the view of attaining composure of mind and steadiness of movement.

Dissections on the cadaver should be made with a view of determining not only the relationship of various parts but the readiness with which the eyeball is affected by operative procedures. Whenever possible the various ophthalmic operations should be performed upon the cadaver, always remembering that the resistance of the eye in the cadaver is somewhat different from that in the living human being.

Bajardi has recently published a stereoscopic atlas in which the

double pictures show very well the various steps in the operation for senile cataract, discission, iridectomy, etc. For the beginner this ought to be of valuable assistance and is recommended to those surgeons who desire to obtain as faithful a representation of the principal operations on the eyeball, as can be had apart from their actual performance on the human subject.

For acquiring operative technique nothing is better than *operations on animal eyes.* For the various operations requiring opening of the globe pigs' eyes may be used, and they offer the advantage of being



Simple Phantom Face, for Eye Operations.

nearest the size and appearance of the human eye. Bullocks' eyes show the relationship of various parts on a larger scale, and for that very reason are not as suitable as the pig's eye. Another disadvantage of the bullock's eye is that it is too large for the instruments ordinarily used for ophthalmic operations, and in the acquiring of technique for ophthalmic operations it is necessary that the instruments and material correspond as nearly as possible to conditions in actual work. What has been said concerning bullocks' eyes applies equally to sheep's eyes, which also are larger than the human eye.

Pigs' eyes are readily obtained and they should be taken from the animal soon after being killed or before any change has taken place. If the cornea has become opaque or clouded as a result of scalding or too long exposure to the air after the animal has been killed the eye is practically useless for operative work. If it is intended that the eyes shall be used within a few hours they can be kept in plain water until so used, in order to preserve their life-like appearance. If, how-

ever, the eyes are to be used later they should be preserved in a one-tenth of one per cent. solution of formaldehyde, in which solution they will remain quite unchanged four or five days. If the preserving solution is made stronger it hardens the eyes so that they are unfit for operative work. But when preserved the tissues undergo certain changes which materially alter their resistance, and hence it is always better to use the eyes when fresh, and this is particularly true when practising the more delicate and intricate ophthalmic operations.

The pig's eye is particularly adapted to the work of acquiring operative skill for the performance of all operations requiring opening of the eyeball, such as cataract extraction, iridectomy, discission, etc. For operations upon the eyelids the cadaver should be used.

Several ingenious means of holding pigs' eyes for operations have been suggested but probably the best is the *Vienna mask* (see the figure) which is a hard-rubber mould of the human head, with openings for the eyes, into which is inserted by a spring and catch the serrated clamp firmly holding the pig's eye so that it gives much of the appearance and relationship to surroundings that would be present in the human eye. By an ingenious arrangement the eye can be fastened tightly or loosely, and the mask is usually arranged so that it can be placed in any position, imitating the position of the head of the human. Most of the other masks in the market, including the *papier maché* phantom faces, are either good or poor imitations of the Vienna mask. For training the hand and following out the steps of various ophthalmic operations nothing excels operative work upon pigs' eyes in the Vienna mask.

For those who do not have access to a Vienna mask or do not care to purchase one, a cheap and very efficient mask may be prepared according to plans suggested by Veasey, which consist in gluing a large, square piece of cork, about one-half or one inch thick, on the lid of a cigar box. The eye is fastened to the cork with tacks (see **Phantom face**) and the lid of the cigar box can be raised or lowered to secure any angle desired.

In placing the pig's eye in the mask it is advisable to place the round end upward, inasmuch as one diameter of the eye is considerably longer than the other. This aids in the making of proper corneal sections, as the iris is not so apt to fall in front of the knife. A portion of the muscles and conjunctiva should remain on the eyeball to give something for firmer support of the clips which hold the eye in the mask. If the home-made mask is used, a considerable portion of the muscles and conjunctiva will prove of advantage in giving a firm anchorage for the tacks which hold the eyeball on the cork.

In operating upon animals' eyes it should be the practice to simulate in every particular all the methods employed in operations upon the human eye, in order to form correct habits and acquire proper technique. The position of the operator and the eye to be operated, the manner of holding the instruments, and the care and disposition of the instruments, dressings and solutions should be given consideration. The position and manner of fixing the eyeball with the fixation forceps, and the amount of pressure to be exerted should be matters of routine. The position of the knife and the position and extent of the incision should also be practised with as much care as though

Eye Phantom for Practising Operations on the Eye.

the eye in a living human were being operated upon, and at the conclusion of the operation proper attention should be given to the toilet of the eye with a view to becoming accustomed to and familiar with the routine procedures of ophthalmic surgery. It is even advisable to invoke the services of an assistant in order to approach as nearly as possible the conditions present at an actual ophthalmic operation.

Another valuable way of acquiring technique is to *perform the various ophthalmic operations upon the living animal, preferably the rabbit.* Large rabbits should be selected, and while many of the operations may be performed under cocain anesthesia, while the rabbit is securely fastened to prevent movement, it is generally better to use general anesthesia.

Aside from operations which require opening of the eyeball, such as cataract extraction, the eyes of animals, particularly rabbits, are adapted to operations upon the muscles. Thus tenotomies and ad-

vancements may be practised with great profit to one who contemplates doing such work upon the human eye.

Operations upon pigs' eyes in the mask, and upon live rabbits' eyes, may also serve to assist the operator in acquiring *ambidexterity*. Seldom, however, will an operator acquire the same skill for the left hand that he possesses in the right, and the advantages of ambidexterity have usually been greatly over-rated. The right-handed operator will always realize that when it comes to certainty, quickness and delicacy of action his right hand is the more reliable, no matter how much training he may give the left, and it is a duty he owes to himself and to the patient to operate in a manner which holds out the best hope of success under any circumstances which may arise.

It may be true that the person who has been trained from childhood to use one hand as much as the other may learn to operate as well with one hand as the other, but this will not hold good with the average person who has been single-handed up to the time that his operative experience begins. To him the best results under all conditions will come from the hand that is used to the most exacting work, and whose natural function has been increased by appropriate training. It sounds very well for an operator to say that he makes his corneal section in cataract extraction with the right hand when operating upon the right eye, and with the left hand when operating upon the left eye, and the practice may look well to an audience, but the operators are exceedingly few in number who can use one hand as well as the other, and it is a sacrifice of some of the chances for the highest type of success when the operator fails to use the hand which he knows is the one with which he can do best under any and all conditions.

Many operators are apparently ambidextrous and operate successfully and skillfully with the left hand, but it may be seriously questioned if such operators in an emergency could be depended upon to do as expert work with the left hand as the right, and one never knows when an emergency may arise which will tax to the utmost the suppleness, promptness and delicacy of action sometimes required of an operator, and it is then that it is the height of absurdity to claim that the left hand can be depended upon to the same extent as the right, which from birth has been trained to do all the exacting work.

Ophthalmic surgery demands a delicacy, a surety of the hand and a dexterity of the fingers extraordinary.

Operators should remember that the patient's interests should be served, and no practice which is known to be attended with unnecessary risk to the eye should be followed, and particularly when it has as its principal reason that of convenience and appearance only.

Many ophthalmic surgeons *operate sitting, but the position is not commendable* as it tends to restrain the movements of the operator. The greatest liberty of action and the utmost independence of movement are necessary to operate well and meet all emergencies. For these reasons one should operate standing, the patient lying on a table whose height brings the patient's eyes on a level or slightly below the level of the operator's elbows when the arms are hanging downward.

Nothing is so detrimental to an operator's suppleness of movement and delicacy of touch as a strained position such as is required to bend over the patient or reach up to him. If the operating table is not an adjustable one, or if the practice followed by many surgeons when extracting cataract of operating upon the patient in the headless bed which he is to occupy, is to be the one of choice, then some mechanical means of elevating the table or bed to the proper height should be adopted. A simple means of accomplishing this is to have four blocks six inches square and of the right height, which may be placed under the four legs of the table or bed. Depressions in the upper ends of the blocks will serve as receptacles for the casters or ends of the table or bed legs and prevent movement.

A very satisfactory *operating table*, particularly for cataract operations when it is desired that the patient be not disturbed after the operation, is the single headless hospital bed with adjustable legs. By means of a tongue and groove and suitable set screws or clamps the legs of the bed may be lowered or raised to any height desired. One end of such a bed may be made higher than the other if occasion demands such a position.

In operating, the arms should be free at the side of the body. The hand should be independent of the arm and not attached to a rigid wrist which will cause the least motion of the shoulder to be transmitted to the fingers. If the hand be only suspended from the arm, the latter will maintain it in the desired position without communicating to it a shock or any trembling, and above all, allow it all the liberty of rotation. The accomplished ophthalmic operator should not have recourse to those movements which proceed from the wrist except for varying the position of the hand, for ocular operations proper should be performed only with the fingers. It is the digital execution which makes the operator in ophthalmology. Our tiny sections require, for the very small excursions of the instrument, a radius which scarcely passes two phalanges. On the other hand, the organ we engage is so delicate, so mobile, and it calls for such nicety, such promptness, such harmony of movement, that he who allows partici-

pation of wrist or elbow faces the risk of sacrificing an eye even while attempting a simple keratotomy.

Concerning the *holding of instruments,* it should be a fundamental rule to hold instruments in the manner which permits of the greatest and most rapid variation of their direction. Instruments with handles, such as knives, should be held much the same as one would a pencil.

The handles of knives and many other cutting instruments for eye surgery are rectangular in shape, for the purpose of permitting the operator to hold the instrument more securely, and to determine more accurately the direction of the blade or point. It prevents involuntary rotations, at the same time permitting the operator to turn the instrument at will.

The handles of knives and similar instruments should be grasped with the pulps of the fingers only—those of the thumb, the index and the medius. The instruments should be held lightly, and execution should be by simple elongation and retraction of the fingers, without the participation of the hand. The position of the fingers should be such that the extremity of the medius is at the place where the shank joins the handle, so that the instrument may receive the greatest liberty of motion without detracting from the surety of its management. The farther the point is removed from the fingers the less surety of action obtained.

In the use of scissors, the thumb is placed into one of the loops, and the ring finger into the other loop, though hardly as far as the articulation of the last phalanx. The bulb of the middle finger rests on the shank of the loop occupied by the third finger, and the index finger is applied at the cross of the scissors. In operating the scissors, the hand must be independent of the arm.

Forceps should be held by the pulps of three fingers only. The thumb should be placed in the center of the shank on one side, the index on the upper half and the medius on the lower half of the opposite shank. The upper extremity of the forceps should never rest on the phalanges of the index, still less be taken into the hand. By holding the forceps as suggested we obtain all the force necessary, and we may impart to its jaws all desired motion.

It is permissible and even commendable to apply the tip of the little finger to a part adjoining the eye to be operated upon. This is not for the purpose of steadying the hand, but of being able to keep in touch with the patient and thus warned of any movements that he may execute with the head.

It not infrequently happens that *an operator may persist for years in pursuing a false technique* and ignoring the most elementary values

of practice because he has had no training during the early part of his career. Text-books have paid scant attention to the manner of acquiring operative technique, and consequently one might regard the subject of minor importance; yet no one better than the experienced operator knows how vital it is to successful surgery. It is with a hope of attracting the attention of beginners to some of the idioms of ophthalmic surgery that the following suggestions are offered.

As the patient about to be operated on is generally under a local anesthetic only, a discreet silence should be observed, not only by visitors and such friends as have been admitted to the operating room, but by the assistants themselves. The operator only is allowed to speak (especially to the patient), and everyone in the room should absolutely, minutely and silently obey his orders, expressed and understood. The less whispering there is among spectators the better it is for the operator and patient. There is nothing more annoying and distracting to both these principals, and hardly any act more impolite than a muttered conversation carried on about the operating-table during the solution of a serious surgical problem requiring the fullest attention and mental concentration of two persons so vitally interested in the result. This regulation is made entirely in the interests of the patient and is not intended for the glorification of the chief surgeon.

It is always well to remind the patient that he is expected to aid the operator and then drill him in his duties. It is not desirable to explain the steps of the operation to him but the exact character of the assistance expected of him should be clearly set forth. He must not speak during the operation except to ask a question or two that may seem important or for such directions as he regards as essential. Preliminary exercise in the manner of opening and closing the lids, of looking up, down, in or out, and, if he happens to be very deaf, signals to indicate these movements should be agreed upon beforehand and the patient drilled in them.

While care and tact should be employed in dealing with aged, nervous or ignorant people, they should be warned to keep as quiet as possible, to follow directions implicitly and not to squeeze the lids together, to move the head or to touch the field of operation with the hands. The patient should not, during the operation, hold his breath, nor should he contract the muscles of his lids, face or neck. It is not a bad plan to request nervous or stupid patients to keep the mouth slightly open and breathe through it during the ordeal. If this plan be followed the difficulties just named are generally avoided. It is advisable not to talk to the patient about the operation any more than

is absolutely necessary, and nothing should be said that will have a tendency to discourage him or make him unduly anxious about the ultimate result.

The *assistant*, who may in all respects be as experienced and as expert as his principal, should thoroughly acquaint himself with the intent of the approaching operation, should consider its possible complications and should see that all necessary solutions, instruments and appliances are ready at hand, in good condition and sterilized. He should confer with the operator and endeavor to learn just what the latter expects of him. He should follow the operator's lead and give advice only when called upon. He ought not to place his body, hands or head in the way of the operator more than is absolutely necessary; he ought to have each instrument ready in advance of the operator's actual need and, above all, see that they are not mislaid during the operation. It is a good plan to have the instruments placed in a pan (filled or not with a sterile fluid) and not on a table, as they are more easily kept in order. Knives or other instruments having a delicate cutting edge which the slightest injury will impair, may be laid in racks. When the operator is finished with a certain instrument it should at once be laid in a particular part of the receptacle. There is nothing more disconcerting to the operator than to be obliged to pause at a critical stage of an operation while the principal assistant, nurses and, perhaps, bystanders join in a hunt for a knife or seissors that is playing hide-and-seek among the dressings and towels on the operating table. Even if the forgetful operator throws an instrument down instead of handing it to his assistant the latter should at once rescue it and return it to the instrument pan.

If there be more than one assistant each should attend strictly to his particular duties and never, unless requested by the operator, undertake the work of another. When dealing with very nervous patients it frequently is advisable, if not necessary, for a second assistant to support the patient's head during the operation, by placing the hands on each side of the patient's face. This not only steadies the head of the patient, so necessary for the success of the operation, but has a tendency to calm his nervousness.

The opening and closing of the lids may be governed during an operation either by the fingers of the assistant or operator, or by various instruments such as the speculum, or the lid elevator.

There are many advantages connected with the use of the fingers. They irritate the patient less than the speculum and permit of rapid and frequent closure of the lids at critical moments; as, for example, should the patient lose control of himself and violently press the lids

together the presence of a speculum is embarrassing and adds to the danger of damaging the eye. Also in passing from one stage of the operation to another it is desirable to close the lids gently but quickly, and that is best accomplished in the absence of lid instruments.

The repeated opening and closing of the lids is desirable to prevent the drying effects of cocain on the anterior epithelium of the cornea—a condition as undesirable during an operation as it is objectionable from the standpoint of possible infection after it.

The effective employment of the fingers instead of instruments involves, of course, a practiced assistant. He should exercise just the correct amount of "pull" upon the eyebrow in elevating the upper lid, and upon the skin of the lower margin of the orbit in drawing down the lower lid. Above all, he should never press upon the eyeball.

The use of the thumb and fingers by the assistant is particularly indicated in short operations, where prompt opening and closing of the lids are needed; also in operations attended by two assistants or where a second one is not required, because control of the lids is the only act the assistant can be called upon to perform; it will occupy all his time and attention and he will not be able to render any further aid, such as sponging, handing out instruments, using the irrigator, etc. An example is in the ordinary extraction of senile cataract.

If the eye is deeply set in the orbit the upper lid cannot be sufficiently retracted to clear the field of operation without dragging forward, the outer canthal tissues. The latter stand in the way of the operator, and the situation is rendered still more difficult by the finger or thumb of the assistant on the eyebrow so that cutting instruments or forceps are not easily entered at the upper limbus corneæ. The second assistant may draw the external angle of the lids outward, but a third person at the head of the patient generally adds one more obstruction. On the whole, such cases are best dealt with by the aid of a speculum.

Quite a few operators employ a combination of these methods; a speculum is employed during the first act; (iridectomy, cataract extraction); it is then removed and the assistant's fingers perform the office until the completion of the operation. This plan covers that part of the procedure in which the use of the fingers is most valuable.

It is very important that the lids should be placed under control in a certain definite manner. Having carefully dried the skin over and about the orbit the patient is directed to close the eye as in sleep. If the assistant stands at the left side of his patient and is about to raise the upper lid, he smoothly covers his thumb or forefinger with gauze; or he will find a gauze finger-stall, tied with tapes about the wrist, a

more effective device. In this way the slipping of the controlling digit on the lid, damp from the irrigating solution, or from perspiration or other secretion, is prevented.

The assistant lays the ball of his finger or thumb over the middle of the palpebral fissure so that its tip covers the lower lid. He then slowly, and without undue pressure, draws the lid upwards so that when the lid edge corresponds with the upper orbital margin the tip exactly corresponds with the lid margin. From that time on until he releases his finger-control he should exert mild pressure of the lid upon the margin of the orbit. He should under no circumstances allow the finger to touch or press on the eyeball, and he should hold the fingers and hand flat on the head of the patient so that they are least in the way of the operator.

The lower lid is drawn down and kept in position with the left hand in the same way as the upper lid is retracted.

Generally both lids are opened, the upper one first, but in operations that involve wide incisions at the upper limbus it is better, after these are made, always to withdraw the lower lid first so as to avoid contact of the interior palpebral margin with the upper edge of the wound. If this rule is not remembered the lid edge may be pushed into the open wound, an accident sometimes followed by immediately serious consequences or, occasionally, by late infection of the incision.

Although the speculum enables one to dispense with at least one assistant, in that it holds the lids apart, yet they do not prevent a nervous or an unruly patient from exerting pressure upon the eyeball; indeed, the limbs of some instruments actually provide a sort of fulcrum on which the orbicularis may act and compress the globe even more effectually than if no speculum had been introduced. It is for this reason a good plan, during cataract extraction or other procedure in which the eyeball is opened, to remove the speculum after the corneal or sclero-corneal incision has been made and have the lids separated by the aid of an assistant's fingers.

Another plan, especially valuable in prominent or projecting eyeballs, is to have the assistant raise the speculum (thus pushing the lids forward and away from the globe) on the least suspicion that the patient is about to squeeze his lids together. In these cases the powerful anterior fibers of the orbicularis palpebrarum are able to compress with increased force the unresisting eyeball. For small and deeply-placed eyes this danger is not so great and, as we have already seen, for such the speculum is, perhaps, to be preferred to the assistant's fingers.

To introduce the speculum into the right eye correctly the upper

lid is drawn upward with the left forefinger of the operator who stands behind the patient in the same manner as described in the use of the fingers as a means of separating the lids, the patient being meanwhile directed to look down. This act raises the margin of the upper lid from the globe, when the upper limb of the closed or partially-closed speculum is gently inserted parallel to the palpebral margin, between lid and eyeball, and pushed toward the upper sulcus. The forefinger is now removed, the patient directed to look down, the lower lid drawn downwards, the lower arm of the speculum inserted in the same fashion as the upper, the forefinger again removed—and the instrument is in place. The patient is now asked to open the eyes widely, the spring with which most specula are provided causes the arms to separate and follow the lids. When the lids are sufficiently open the speculum is locked, generally by means of a screw. If the patient does not open the eyes widely enough, the arms of the speculum are further spread by means of the finger. Some operators prefer a speculum without a lock or stop of any sort, as they would rather risk the patient's squeezing his lids than the loss of the valuable instant of time required in an emergency to unscrew or undo the mechanism necessary to unlock the speculum. For this and other reasons Czermak prefers Mellinger's speculum. This instrument is of the simplest construction, has no lock, screw or other complicated mechanism, but is held open automatically by the pressure of the lids. All its parts are smooth, readily cleaned, easily taken apart, and so fashioned that the branches do not irritate or invite the patient to squeeze up his lids. They have, however, one serious failing; should the patient persist in tightly shutting his lids, it is almost impossible to remove the instrument;—a very serious matter in case of actual or threatened loss of vitreous, for instance.

Czermak suggests a remedy for this defect which, he believes, is due to the construction of the wire loop that enfolds the lid margins. Since this modification he has also been able to dispense with the spiral spring that separates the arms as well as the screw for locking them.

A third method of separating and fixing the lids is by means of the retractor or lid elevator. This valuable instrument is generally found of several sizes in the form originally invented by Desmarres. The smaller sizes are particularly intended for use in operations on the cornea and at the limbus. When in place the flat surface of the palpebral end entirely covers the lid margins and the cilia. However, the handle is rather in the way when fixation forceps and other instruments (especially keratomes) are to be used on the upper aspect of the globe, unless the patient is unusually quiet and obedient. This

objection is almost insurmountable when the eye lies deeply in the socket. The objection may be overcome, however, by constructing the lid elevator so that its handle will be rather long and curved backward to lie close to and conform to the head.

To introduce the lid retractor the upper lid is raised with the forefinger in the manner previously described, the rounded end is inserted between the eyeball and the palpebral margin and gently pushed to the upper fornix. The handle is then pulled firmly forward, so as to draw the lid away from the globe without pressing the sharp edge of the rounded plate too much against the upper sulcus. The assistant should not, on the one hand, press the lid too strongly against the margin of the orbit because that is painful, nor should he drag too much on the periphery of the lid lest the latter slip off the end of the retractor and fall against the eyeball at a critical stage of the operation. If he will remember to draw as much of the lid as possible away from as much of the globe as he can without hurting the patient he cannot go far wrong. It will then be noticed how completely and painlessly he can control the movements and how impossible it is, even in prominent eyes, for the nervous or stupid patient to squeeze the lids against the eyeball.

By far the commonest instrument for fixation is the well-known fixation forceps provided with three or four teeth. The latter should not be, as they often are, provided with sharp points or cutting edges, as they lacerate the tissues. The purpose of the forceps is to grasp the soft parts and not to cut them. Elschnig recommends a straight forceps provided with three teeth, one blade with one tooth, the other with two, set at an angle of 45 degrees. When the blades are placed about two mm. apart near the sclero-corneal junction, gently pressed against the globe and then closed, the episcleral tissues are caught in the teeth without damaging them, yet fixing the eye securely.

The fixation forceps are generally placed close to the limbus because the conjunctiva in that situation is less movable than elsewhere. If the operator should tear the mucous membrane and still desire fixation, the underlying scleral tissue, or even the tendon of a straight muscle can be grasped, but the latter method is a painful one and to be avoided as much as possible. Apart from ignorance or carelessness this accident is most likely to happen when the patient is under a general anesthetic and the operator attempts to drag in the opposite direction an eyeball that has rotated beyond his reach. It is not to be forgotten that gentleness, quite as much as firmness, is a part of ophthalmic operations.

Generally the teeth of the fixation forceps are placed on the opposite

and corresponding part of the globe to the point of puncture. In the corneal incision of cataract extraction with an upper flap the area of fixation is best chosen a few mm. below the meridian of the counter-puncture so that the knife, as it cuts its way out, may not come in contact with the forceps.

The assistant should particularly bear in mind while holding the fixation forceps that neither pressure nor dragging movements should be made upon the eyeball. The purpose of the forceps is to steady or fix the globe as securely as possible without injury to its tissues or discomfort to the patient. If it is necessary to rotate the globe the patient should be requested to look in the required direction while the forceps, although held in their closed condition, should simply follow the globar movement. If the patient be under a general anesthetic, or if for any other reason he cannot look in the required direction, the eyeball may be rotated, not pulled or pushed, the forceps being always held at the same tangent to the globe. When it is desirable to fix the eyeball with greater security than usual, as for example in trephining the cornea, two forceps are employed, one at each end of the same corneal meridian. These are held in each hand of the same assistant. Double fixation forceps have been devised for this purpose, but in general these are not very satisfactory, because it is difficult to secure equal fixation with the two sides of the forceps, and there is more apt to be unnecessary and perhaps dangerous traction on one side or the other if there is a sudden and unexpected movement of the eyeball.

There is, as a rule, not only no need for a catch, or lock in the fixation forceps, but they are generally a nuisance if not a positive danger, because too much valuable time is wasted in applying and releasing them.

If there is a particular objection to making even the slightest wound in the conjunctiva and no special reason for securing fixation of the globe, as in tattooing the cornea, a blunt forceps may be used—one provided with serrated ivory, celluloid or hard-rubber terminals.

In some cases, as in enucleation of the globe, operations on the vitreous, etc., where forceps are inconvenient, a needle and thread are passed through the conjunctival and episcleral tissues at the limbus and brought out about a cm. from the point of entrance. The ends of the suture, which may be about 23 cm. long, are held by the assistant who can easily rotate the globe to any desired condition.—(A. E. B.)

See, also, **Cataract, Senile**; as well as such captions as **Iridectomy** and **After-treatment.**

Operculum oculi. (L.) The eyelid.

Ophioxylon serpentinum. EAST INDIAN SNAKEWOOD. *Ophioxylon trifoliatum.* A twining plant or erect shrub growing in Ceylon and British India. The root is very bitter, and has an acrid odor when fresh. It contains much starch and a crystalline principle. The milky juice is used as an application in leucoma.

Ophryosis. (Obs.) Spasm of the eyebrow.

Ophryphtheiriasis. (L.) Phtheiriasis of the eyebrows and eyelashes.

Ophtalmie algérienne. (F.) A form of chronic contagious conjunctivitis occurring among the residents in Algeria, especially European soldiers, in which the vesicular granulations were formerly regarded as true neoplasms, distinct from the papillary hypertrophy; doubtless a follicular trachoma.

Ophtalmie des neiges. (F.) Snow-blindness.

Ophtalmie profonde. (F.) Panophthalmitis.

Ophthalmagra. Sudden pain in the eye.

Ophthalmalgia. Pain or neuralgia in the eye; ciliary neuralgia.

Ophthalmatrophia. Atrophy of the eyeball.

Ophthalmectomy. The surgical removal of an eye.

Ophthalmedema. An old term for chemosis.

Ophthalmemicrania. One of the names for epileptoid amaurosis, a form of sudden blindness not confined to epileptics, but considered by some to be epileptic in its nature.

Ophthalmempasma. An old term for a dry collyrium.

Ophthalmentozoon. An ocular parasite.

Ophthalmia. An inflammation, generally severe, of the eye or of the conjunctiva. This term, once supposed to designate a definite pathologic entity, is now known to have a vague application and to signify almost any form of inflammation of any portion or portions of the ocular apparatus.

Ophthalmia abdominalis. An old term for a conjunctivitis supposed to be intimately connected with some disease of the abdominal organs.

Ophthalmia angularis. CANTHITIS. Inflammation at the angle of the eyelids.

Ophthalmia, Ante-partum. See p. 505, Vol. I of this *Encyclopedia.*

Ophthalmia, Aphthous. Conjunctivitis phlyctenulosa maligna.

Ophthalmia arida. XEROPHTHALMIA. Xerosis of the conjunctiva, which has become rough, thickened, dry, and cuticular. It then assumes a dirty, grayish-white appearance, due to atrophy of the conjunctiva, the subconjunctival tissue, and even the tarsus, with destruction of the glandular apparatus. It follows long-continued and severe conjunctivitis. See p. 3075, Vol. IV of this *Encyclopedia.*

Ophthalmia, Army. A form of purulent conjunctivitis; trachoma.

Ophthalmia artefacta. A name given by H. D. Bruns (*Trans. Am. Ophth. Soc.*, 1913) to repeated self-inflicted injuries of the anterior parts of both eyes, by which a patient reduced herself almost to blindness.

Ophthalmia arthritica. Ophthalmia due to gout. See **Iritis**; **Scleritis**; as well as **Uveitis.** See, also, p. 5617, Vol. VII of this *Encyclopedia.*

Ophthalmia bellica. Military ophthalmia. Purulent ophthalmia; so called because it is common among soldiers. Sometimes applied to trachoma.

Ophthalmia biliosa. Ophthalmia supposed to be due to hepatic disease.

Ophthalmia brasiliana. A term applied by Gama Lobo to a disease occurring in Brazil among ill-nourished negroes, in which the conjunctiva is whitish-gray, with a dry, tallow-like surface, over which the tears run without moistening it. This extends to the ocular conjunctiva, and then the cornea is involved, and sloughs.

Ophthalmiac. A person affected with ophthalmia.

Ophthalmia cachectica. Ophthalmia supposed to be due to some cachexia.

Ophthalmia cacochymica. An old term for an ophthalmia supposed to be due to a dyscrasia.

Ophthalmia cancrosa. A term applied by Sauvages to cancer of the eye.

Ophthalmia catarrhalis pustularis. A term applied by Arlt to a form of ocular conjunctivitis characterized by an injection of the blood-vessels, usually near the outer canthus, with edema and swelling of the surrounding conjunctiva, and the formation of a small pustule.

Ophthalmia consensualis. Ophthalmia transferred from a distant diseased organ; ocular metastasis.

Ophthalmia, Dry. Xerophthalmia. See **Ophthalmia arida,** as well as p. 3075. Vol. IV of this *Encyclopedia.*

Ophthalmia, Egyptian. A name for trachoma.

Ophthalmia electrica. See p. 4226, Vol. VI of this *Encyclopedia.*

Ophthalmia epiphora. See **Hygrophthalmia,** p. 6809, Vol. VIII of this *Encyclopedia.*

Ophthalmia erethica. (Obs.) Ophthalmia attended by pain or some other affection of the nervous system.

Ophthalmia erysipelatosa. A name given by Arlt to a severe form of catarrhal conjunctivitis, accompanied by great swelling of the tarsal and retrotarsal portions and numerous small ecchymoses.

Ophthalmia externa. Conjunctivitis.

Ophthalmia fetalis. Ophthalmia occurring during fetal development and causing, among other changes, ankyloblepharon.

Ophthalmia, Fungous. Inflammation of the eye caused by fungi.

Ophthalmia gallica. Venereal disease of the eye.

Ophthalmia gastrica. Ophthalmia supposed to be caused by gastritis.

Ophthalmia glandularis. Inflammation of the Meibomian glands.

Ophthalmia, Gonorrheal. See p. 5606, Vol. VII of this *Encyclopedia.*

Ophthalmia hematolytica. An old term for an eye disease supposed to be due to a lessened amount of fibrin in the blood.

Ophthalmia hemorrhoidalis. An old term for an ophthalmia supposed to be due to the suppression of a hemorrhoidal flux.

Ophthalmia hepatica. See **Liver** captions on p. 7501, Vol. X; also **Hepatic disease,** p. 5809, Vol. VIII of this *Encyclopedia.*

Ophthalmia, Humid. (Obs.) Chemosis of the conjunctiva and eyelids.

Ophthalmia hydatomeningica. Inflammation of Descemet's membrane; a descemetitis.

Ophthalmia, Inclusion. See **Conjunctivitis, Inclusion,** p. 3111, Vol. IV of this *Encyclopedia.*

Ophthalmia interna choroidealis. Choroiditis.

Ophthalmia interna hyaloidealis. Hyalitis.

Ophthalmia, Intrauterine. See **Antepartum ophthalmia,** p. 505, Vol. I of this *Encyclopedia.*

Ophthalmia, Jequirity. A form due to poisoning by jequirity. See under **Abrus,** p. 33, Vol. I of this *Encyclopedia.*

Ophthalmia, Lymphatic. See **Conjunctivitis, Phlyctenular.**

Ophthalmia, Malignant. An acute form of purulent ophthalmia (panophthalmitis) that rapidly destroys life by extension of the inflammatory process to the brain.

Ophthalmia melanotica. An old term supposed to be synonymous with general melanosis of the eyeball.

Ophthalmia membranarum. A term suggested by Cullen for chemosis of the eye.

Ophthalmia menstrualis. An old term for a disease of the eye supposed to be due to suppression of the menses.

Ophthalmia, Mercurial. Ophthalmia supposed to be caused by the administration of mercury.

Ophthalmia, Metastatic. See **Metastasis, Ocular,** p. 7664, Vol. X of this *Encyclopedia.*

Ophthalmia, Migrating. See **Sympathetic ophthalmia.**

Ophthalmia migratoria. A synonym of sympathetic ophthalmia.

Ophthalmia, Migratory. See **Sympathetic ophthalmia.**

Ophthalmia, Military. OPHTHALMIA MILITARIS. Purulent ophthalmia;

so called because it is, or has been, common among soldiers. Sometimes the term is used for trachoma.

Ophthalmia, Milk. An old term for a form of ophthalmia attributed to milk metastasis.

Ophthalmia morbillosa. The conjunctivitis of measles.

Ophthalmia mucosa. A name for conjunctivitis.

Ophthalmia neonatorum. Blennorrhea neonatorum. Infantile conjunctivitis. Gonorrheal conjunctivitis of the new-born. The subject has already been discussed under various headings, but especially on p. 1019, Vol. II; under **Conjunctivitis purulent,** p. 3135, Vol. V; **Blindness, Prevention of,** p. 1148, Vol. II; as well as under **Conservation of vision,** p. 3190, Vol. V of this *Encyclopedia.* Other relations of this most important subject are treated under such collateral headings as **Gonorrhea, Ocular relations of,** p. 5606, Vol. VII; **Institutions for the blind,** p. 6372, Vol. VIII; **Blindness, Causes of,** p. 1125, Vol. II; and **Bacteriology of the eye,** in particular, p. 812, Vol. II of this *Encyclopedia.*

A practical summary of the laws governing the attempt to prevent the ravages of ophthalmia neonatorum, and the attitude of the medical profession towards these, is presented by Geo. H. Thompson (abstract in *Br. Jour. of Ophthalm.*, from the *Boston Med. and Surg. Jour.*, May 25, 1916). He agrees with those observers who believe that mildness of gonococcal ophthalmia in the infant as contrasted with its severity in the adult is by supposing that the mother confers a strong degree of immunity upon the child. He does not agree with the view according to which the mild disease in the infant is due to the fact that the infection has long lain dormant until roused into activity, whereas in the adult it occurs at the height of an attack of acute urethritis, when the infective powers of the micro-organism are presumably greatest. The author regards cases which occur before the second day after birth as due to intra-uterine infection, and those after the tenth day, to secondary infection. His views as to the pathogeny of corneal ulceration differ from those commonly held, since he believes that the ulceration is usually caused by traumatism from the fingers, either of the infant or of the attendant. Hence (quite consistently), he advises, that in the treatment of the malady the baby's arms should be confined, so that he cannot reach his eyes, and in applying lotions, that the use of undines or of syringes be avoided. There is another reason for not employing syringes (not mentioned by the author), namely, the danger of infecting one's own eyes, of which unfortunate casualty the reviewer has witnessed a number of instances.

As regards treatment, silver nitrate is not used by Thompson, who

depends upon 25 per cent. argyrol or 4 per cent. protargol. Despite the fact that some [including the Editor of this *Encyclopedia*] think lightly of its germicidal properties, Thompson has always been satisfied with argyrol in suppurative conditions about the eye. The eyes should be kept clean with boric lotion or normal saline. The slighter corneal complications are treated with hot fomentations, the local application of carbolic acid or of tincture of iodine, the operation of corneal section being reserved for the more serious cases. He does not believe in the application of either atropin or physostigmin.

He mentions a surprising fact reported by Derby, viz., that in a series of cases reported from the Massachusetts Charitable Eye and Ear Infirmary 23 per cent. were unilateral. This is very different from the experience in Europe, where most cases eventually become bilateral. Indeed, one English observer went so far as to assert that unilateral cases were never seen.

Comparing the results of cases treated in private and in hospital, according to Cheney, Thompson makes some interesting remarks.—Among 116 babies treated in the year 1909 at the Massachusetts Charitable Eye and Ear Infirmary only six became blind, and all of these were brought after ulceration was well established. On the other hand, in eight American cities, of sixty-one medical men, each of whom was confronted at least once during 1909 by a case of ophthalmia neonatorum, thirty-nine, or over 64 per cent., neither asked at any time for expert help, nor transferred the cases to hospital, but "invariably tried their inexpert hands at restraining the disease which they had failed to prevent." These physicians treated forty-four cases, and they failed to save the sight of nine babies. "For these physicians the best that can be said is, that they reaped the result of their own laxity in 20 per cent. of their eye cases; or, in other words, they failed to prevent blindness in every fifth case."

As showing the unwisdom of giving a definite prognosis, Thompson mentions a couple of cases, in one of which a corneal ulcer developed when discharge had practically ceased, and in the other where the baby, under similar circumstances as regards discharge, developed fatal meningitis.

Before discharging a case Thompson takes two negative smears at intervals of forty-eight hours. He mentions the circumstance that gonococci have been found in the conjunctiva twenty-five days after the eyes were apparently well, and sixty days after the onset of the discharge.

Thompson whole-heartedly advocates the use of silver nitrate, 1 per cent., as a prophylactic, although he mistakenly states that these drops

were those originally recommended by Credé. In point of fact, as well known, the Leipzic professor employed and advocated 2 per cent. silver nitrate.

The American states have no standardized legislation for preventing infantile ophthalmia, and in some, indeed, no legislation dealing with the subject exists. Briefly, in 30 states babies' sore eyes must be reported to the Board of Health. In all states the health officers are required to secure medical attention for uncared-for cases. In 5 states a reporting law is printed on the birth certificate. In 4 states only are births reported early enough to be of assistance in the prevention of ophthalmia. In 9 states a question as to whether precautions have been taken against ophthalmia neonatorum is included in the birth certificate. In 12 states prophylactic outfits are distributed free to physicians and midwives. In 6 states the use of a prophylactic is compulsory. Finally, in 19 states popular educative literature is distributed by State Boards of Health. The city of Boston, which leads all others in preventive legislation, provides notification of birth within 48 hours, the use of preventives in all lying-in hospitals, free distribution of prophylactic, immediate reporting of cases of ophthalmia, the following-up of reported cases, and the authorization of Board of Health to deal with such cases.

Thompson does not join in the hue and cry against midwives as the chief offenders in the causation of ophthalmia. He adduces evidence to show that the disease is actually more frequent in the cases where labor is attended by medical men. He thus reaches a view which the reviewer has voiced for several years past. There are few states where it is compulsory for the midwife to be registered. By the way, Thompson is not quite correct in stating that "in England midwives are compelled by law to use a prophylactic in every case; failure to do so revokes their license." The truth is that the Central Midwives Board (the body which licenses the women) insists that in every birth certain simple precautions, such as cleansing the eyelids shall be taken, but it does not enjoin the employment of any chemical agent.

The author rightly lays stress upon the fact that the extra cost of educating a blind child approximates 3,000 dollars, and, further, that the estimated earnings of a blind individual are only one-half those of a sighted person. He concludes that the loss to the community of each person blinded from childhood must be about $13,000. As he points out, this amount would pay the salary of a capable woman for fourteen years, and he advocates the employment of such women, much in the same way as "health visitors" in England.

Ophthalmia neuroparalytica. Ophthalmia—especially keratitis—caused by paralysis of the fifth nerve.

Ophthalmia nodosa. Conjunctivitis and other lesions of the eye induced by injuries from caterpillar hairs. The disease is especially characterized by the formation of round, gray swellings where the hairs are embedded.

This subject has already been partially discussed under the caption, **Caterpillar-hairs,** p. 1781, Vol. III; under **Conjunctivitis nodosa,** p. 3123, Vol. IV; and under **Iritis nodosa,** p. 6667, Vol. IX of this *Encyclopedia*. It may, however, be added here that the researches of Walter Parker (*Jour. Am. Med. Assocn.*, p. 639, Aug., 1910) furnish our most recent and complete review of the subject. He finds that ophthalmia nodosa was first described by Pagenstecher in 1883 as "caterpillar-hair ophthalmia," later by Wagenmann as "pseudotuberculosis," and by Saemisch as "ophthalmia nodosa." It shows a tendency to form tubercle-like structure, often showing nodules appearing singly or in crops, progressing mostly with exacerbations and remissions. The patient does not always give a history of caterpillar contact, the diagnosis being made with the aid of the microscope.

The disease is most common among those who work in the woods and fields. In most cases, the caterpillar falls or is thrown into the eye of the patient, or more rarely the infection occurs through free hairs. Ralzeburg pointed out the varying susceptibility of different persons, and Teutschlaender proved by experiments on himself that the skin varies as to susceptibility according to its thickness. He obtained a marked reaction on the thin skin of his forearm, but practically none from the thicker skin of the finger, the same caterpillar being used in both tests. The hairs have been demonstrated in the conjunctiva, episclera, sclera, cornea, iris and in one case in the choroid.

As a rule, the first symptoms occur soon after the trauma, although in exceptional cases no symptoms appear until the nodules are present. When the cornea is involved the initial symptoms are often most severe. They consist of the sensation of a foreign body in the eye, itching or burning, with lachrymation and photophobia, all being heightened by rubbing. These symptoms are followed by swelling of the lid, pericorneal injection and edema. There is usually loss of corneal epithelium, either through wounding by the caterpillar, or through the rubbing by the patient. The initial stage continues as long as the hairs cause irritation, either mechanically or chemically, or until the hairs penetrate the tissues and become encapsulated, which occurs from the fourth to the eighth day. At the end of the second week or the beginning of the third, the first nodule or nodules appear, thus ushering

in the typical stage of ophthalmia nodosa. Should the hairs be eliminated the disease may be aborted without developing a nodular formation.

Karsten in 1848, as quoted by Leydig, demonstrated the fact that the irritating variety of caterpillar *(Saturna)* has skin glands which discharge directly into the wide canal of the chitin integument, which canal passes into the base of the hair, while the non-irritating varieties *(Vanessa, Acraca, Argymus)* do not have these glands. In 1855, Leydig confirmed the work of Karsten and demonstrated the presence of the gland in the *Bombyx rubi (Barenraupe)*.

Other explanations than the Karsten-Leydig medullary poison theory have been advanced to explain the peculiar symptoms that follow the entrance of hairs of certain caterpillars into the tissues, among which are the Gossen-Fabre varnish theory, namely, that the poison is a by-product of the organic metabolism of the caterpillar and adheres to the outside as pollution; and the Stargardt resorption theory, namely, that the toxin is a product resulting from decomposition of the chitin which the absorption of the hair brings about. The possibility of bacterial infection as the exciting cause has been disproved by negative results obtained by de Schweinitz and Shumway, who transplanted a piece of conjunctiva rich in nodules into the anterior chamber of a rabbit; by the results of the tuberculin injections of Kruger and Becker; and also by the microscopic examination of the excised material by Wagenmann and others. The offending hair appears to be sterile (possibly owing to the disinfecting action of the contained formic acid as suggested by Mitschenkoff) and the symptom-complex cannot be explained on the theory of an accompanying bacterial infection.

The caterpillar hairs are more or less pointed, tubular structures, which are either needle-like and rigid or worm-like and flexible. Their surface is either smooth or covered with barbs or spinules. They are composed of a chitinous substance, which surrounds the medullary canal. Into this canal the secretion of the gland is emptied. The hairs are very numerous and easily detached. Owing to the fact that the barbs all point upward the hair must enter the tissues base foremost.

Formic acid, which plays such an important part in insect poison, has been proved to be present in the gland secretion. When the hair enters the tissues more or less toxin escapes from the medullary canal, and the initial symptoms are produced. The course is chronic—may cover months or years. According to Teutschlaender, the latent period, interrupted by acute exacerbations, is so characteristic of the disease that he agrees with Meixner that it is almost pathognomonic

for ophthalmia nodosa. Recurrences have been reported at periods of time varying from four days to over three years. The patient in the latter case had the first recurrence one month after the time of infection, the third attack three years later, and the fourth after another month. According to different theories, the recurrences may be owing to a new infection; the wandering of a non-encapsulated hair; or to chemical action. From an analysis of the clinical observations it would seem that in addition to the mechanical irritant another agent must be present, which gives to the clinical history its peculiarity, and they believe that the idea of a chemical toxic agent best explains not only the clinical manifestations of the initial attack, but is the cause of the recurrent attacks as well. The details of the process as given by Teutschlaender are as follows:—

The initial inflammation subsides, some of the hairs being eliminated, while those remaining behind have their mechanico-chemical irritation hindered through the process of infiltration and encapsulation. But so long as the foreign body or its poisonous substance have not been absorbed or eliminated the process is not permanently stopped. Either there is an intensification of the poison, or else the protection of the tissue is weakened. The tissue changes, which during the inflammatory period caused a halt in the work of the etiologic factor, undergo a certain metamorphosis during the latent period. The edema and cell infiltration disappear and the protection is lessened. At the same time changes are taking place in the hair. The chitin-layer is being absorbed and larger openings in the medullary canal allow the poison to escape and the chemical agents to accumulate at the inner part of the nodule. When a sufficient amount has accumulated, or the protection is weakened or gone, an irritation is set up and the reaction appears, resulting in a recurrence of the initial process. This cycle goes on until the poison has all been carried off, when the hair remains in the tissue as an unirritating foreign body.

While the clinical picture of ophthalmia nodosa is characteristic, the anatomic changes are not. The first change is an intensely active hyperemia soon associated with round-celled infiltration which appears especially in the direction of the foreign body and is accompanied by more or less edema. Those hairs which are superficially situated and circumscribed by the cell infiltration may be pushed out when healing follows. The mechanico-chemical action calls forth a cell diapedesis and proliferation until a sufficiently protecting wall is built up. While in the early stage of the nodule formation round-celled leucocytes are the predominating element, later epithelioid and giant cells are added.

The conjunctiva is the most frequent site of infection and it is here

that the typical nodules so suggestive of tubercle are formed. The number of nodules varies greatly—in one case twenty-seven were demonstrated (de Schweinitz and Shumway). They are grayish-yellow in color and between them there is marked congestion of the conjunctival and episcleral vessels.

In the cornea, the pericorneal injection appears almost immediately, and on the third day the infiltration is noticeable. While the areas of infiltration are well defined, they are not elevated as is the case in the conjunctiva and iris. This is owing to the fact that the cornea is non-vascular.

The *iris is far more frequently affected than the cornea.* The hair perforates the cornea either through the force of the fall of the caterpillar or through the rubbing of the eye by the patient. With one part still sticking in the cornea, the hair may bridge the anterior chamber and by means of its spinules become attached to the iris, which by its movements in dilating and contracting may draw the hair away from the cornea. At the point of entrance of the hair into the iris hyperemia and swelling occur, followed by cell infiltration, resulting in the formation of a nodule. In most cases the reaction is not severe enough to jeopardize the vision, although in one reported case an iridochoroiditis plastica followed with blocking of the pupil, and in another the eyeball shrunk, resulting in phthisis bulbi.

One patient observed by Reis twelve years after the occurrence of the infection showed seven scars in the conjunctiva, one nodule in the episclera (from which a well-preserved hair was extracted), an opacity in the cornea (from which a hair was removed), and in the choroid a Y-shaped streak of choroidal degeneration bordered with pigment with a greenish reflex at one extremity, which Reis thought probably was a hair.

In a majority of the reported cases there is a history of injury to the eye by a caterpillar; in the absence of this history there is one of sudden onset of the symptoms, consisting of pain, more or less severe, much photophobia and lachrymation. These symptoms tend to subside after a few days, but do not entirely disappear. In the course of a few weeks an exacerbation of all the symptoms occurs. The time between the date of infection and the first consultation has varied from four hours to six months. The period of time that has elapsed between recurrent attacks has been from four days to three years.

The different tissues of the eye affected were as follows: conjunctiva: 24 cases = 62.1 per cent. of 37 cases; cornea: 18 cases = 48.6 per cent. of 37 cases; iris: 16 cases = 43.2 per cent. of 37 cases; cornea, only: 4 cases = 10.8 per cent. of 37 cases; sclera: 3 cases = 8.1 per

cent. of 37 cases; episclera: 2 cases = 5.4 per cent. of 37 cases; choroid: 1 case = 2.7 per cent. of 37 cases.

In every case reported, there was either a definite history of injury with a caterpillar or the presence of a caterpillar hair was demonstrated. There was a history of injury in 27, or 73 per cent., of the cases, while the hair was demonstrated in 32, or 86.4 per cent., of the cases. The species of the offending caterpillar was determined in 16, or 50 per cent., of the cases in which the hair was found.

The following species of the caterpillar were demonstrated: *Bombyx rubi*, 10 times; the *Knethocampa processionea*, 3 times; the *Bombyx pini*, 2 times; and the spinning *bombycina* and the *Spilosoma virginica*, each, once.

The *treatment* adopted in the reported cases has been in the main symptomatic. The local remedies employed have been those usually prescribed in the treatment of iritis. The resemblance of the corneal lesions to those found in keratitis punctata superficialis of Fuchs has led in some cases to the administration of mercury, but without results. Operative treatment has been limited to iridectomy, to combat iritis or increased tension, and for the excision of nodules and hairs.

The *prognosis* in ophthalmia nodosa should be guarded. It will depend on the tissues involved, the severity of the case, and the extent of the structural change present.

Ophthalmia notha. A term applied by Sennertus to catarrhal ophthalmia.

Ophthalmia, Parasympathetic. See **Keratitis, Atypical.**

Ophthalmia, Periodic. A disease of the eye met with in horses, which appears to be of constitutional origin and terminates in loss of vision; also, an ophthalmia which recurs at periodical intervals.

Ophthalmia, Phlebitic. An old term for ophthalmia due to a secondary deposit from a "sharp humor contained in the veins," which was "carried upward and settled in the head;" also a term originating with Mackenzie, for an ophthalmia phlegmonosa secondary to purulent phlebitis or to pyemia.

Ophthalmia phlegmonosa. Purulent ophthalmia.

Ophthalmia phlyctenodes. A name adopted by Sauvages for phlyctenular ophthalmia.

Ophthalmia pruriginosa. OPHTHALMIA PSORICA. Old names for blepharitis.

Ophthalmia puerperalis. Any disease of the eye resulting from the puerperal state.

Ophthalmia pura. OPHTHALMIA PHLEGMONOSA. Obsolete names for phlegmonous ophthalmia.

Ophthalmia purulenta mitior. An old name for, probably, "pink-eye."

Ophthalmia pyorrhoica. Purulent conjunctivitis.

Ophthalmia scorbutica. The keratitis, iritis, or choroiditis (or all three combined), sometimes associated with scurvy.

Ophthalmia scrofulosa torpida. Ophthalmia associated with scrofula.

Ophthalmia, Scrofulous. See **Conjunctivitis, Phlyctenular,** p. 3131, Vol. V of this *Encyclopedia.*

Ophthalmia specifica. Any ophthalmia due to a general dyscrasia.

Ophthalmia sthenica. OPHTHALMIA SYNOCHICA. See **Ophthalmia phlegmonosa.**

Ophthalmia, Strumous. See **Keratitis, Phlyctenular,** p. 3131, Vol. V of this *Encyclopedia.*

Ophthalmia, Subconjunctival. A term applied by von Ammon to a localized scleritis.

Ophthalmia, Sympathetic. See **Sympathetic ophthalmia.**

Ophthalmia tarsi. A synonym of blepharitis marginalis. See p. 1028, Vol. II of this *Encyclopedia.*

Ophthalmia tenebricosa. See **Gutta serena,** p. 5668, Vol. VII of this *Encyclopedia.*

Ophthalmia torpida. Chronic ophthalmia.

Ophthalmia, Transferred. Same as **Sympathetic ophthalmia.**

Ophthalmia trichomatosa. An old term for an insidious iritis supposed to be of trichomatous origin, or to be due to *plica polonica,* an affection of the hairy scalp, of the beard, etc., in which the hairs become matted and stuck together so as to form a more or less stiff, inextricable mass. Though formerly believed to be an independent disease, and by some to be due to a peculiar diathesis, it is now regarded as a simple inflammatory condition induced by filth and neglect.

Ophthalmiatrics. Ophthalmology; also, the treatment of eye diseases.

Ophthalmia tuberculosa. A name given by Sauvages to chalazion.

Ophthalmia universalis. Panophthalmitis.

Ophthalmia uveæ. A term suggested by Sauvages for an ophthalmia (generally glaucoma) caused by displacement of the crystalline lens into the anterior chamber.

Ophthalmia, Vaccine. See p. 5029, Vol. VII of this *Encyclopedia.*

Ophthalmia, Varicose. An eye disease supposed to be associated with varicosity of the veins of the conjunctiva; cirsophthalmia.

Ophthalmia, Venereal. Of the older writers, syphilitic iritis or keratitis.

Ophthalmic artery. See p. 617, Vol. I of this *Encyclopedia.*

Ophthalmic artery, Aneurism of. See p. 461, Vol. I of this *Encyclopedia.*

Ophthalmic balsam. See p. 870, Vol. II of this *Encyclopedia.*

Ophthalmic barberry. BERBERIS LYCIUM. See p. 935, Vol. II of this *Encyclopedia.*

Ophthalmic calometry. See p. 1367, Vol. II of this *Encyclopedia.*

Ophthalmic discs. See p. 4032, Vol. VI of this *Encyclopedia.*

Ophthalmic expert testimony. See **Legal relations of ophthalmology,** in first third of the section.

Ophthalmic furrow. In the embryos of certain insects, furrows from which the eyes develop.

Ophthalmic ganglion. See p. 5344, Vol. VII; also, p. 2235, Vol. III of this *Encyclopedia.*

Ophthalmic hospitals and clinics. This subject has many relations to ophthalmology, most of which have already been discussed, or will be discussed, elsewhere in this *Encyclopedia.* Thus, the architectural and clinical aspects have been treated on p. 6025 in Vol. VIII; others under **Ophthalmology, History of**; as well as under **Pedagogy**; **Knapp,** p. 6850, Vol. IX; **Institutions for the blind**; and **Ophthalmology, Literature of.**

Ophthalmic instruments. See p. 6526, Vol. IX of this *Encyclopedia.*

Ophthalmic jurisprudence. See **Legal relations of ophthalmology.**

Ophthalmic lens. A lens used to determine and neutralize an optical anomaly of vision; a lens in spectacles. See **Lenses and prisms.**

Ophthalmic literature. See **Ophthalmology, Literature of.**

Ophthalmic malpractice. See **Legal relations of ophthalmology.**

Ophthalmic migraine. See p. 7694, Vol. X of this *Encyclopedia.*

Ophthalmic nursing. See **Nursing, Ophthalmic.**

Ophthalmic operations, Skill or dexterity in. For a review of this subject see the major heading, **Operative skill in ophthalmic surgery.**

Ophthalmic prism. A prism used to determine the relative strengths of the extrinsic ocular muscles, and to neutralize the effects of deviations from the normal directions of the visual lines produced by muscular imbalance. See **Lenses and prisms** sections, beginning with p. 7212, Vol. X of this *Encyclopedia.*

Ophthalmic vein. See p. 409, Vol. I of this *Encyclopedia.*

Ophthalmin. A name given to the "virus" of purulent ophthalmia.

Ophthalmist. A little used synonym of *ophthalmologist.*

Ophthalmitis. Inflammation of the entire eyeball.

Ophthalmitis, Migratory. See **Sympathetic ophthalmia.**

Ophthalmitis, Sympathetic. See **Sympathetic ophthalmia.**

Ophthalmitis, Transferred. See **Sympathetic ophthalmia.**

Ophthalmobiotic. A term, adopted by E. S. Bartsch, to mean "pertaining to the development and physiology of the eye."

Ophthalmoblennorrhea. Gonorrheal or purulent ophthalmia. See p. 3135, Vol. V of this *Encyclopedia.*

Ophthalmoblennorrhea gonorrhoica. The term applied by Lohmeyer to gonorrheal ophthalmia.

Ophthalmobrachytes. (L.) Shortening of the antero-posterior axis of the eye, i. e., a myopic eye.

Ophthalmocace. Caeophthalmia, or exophthalmic goitre.

Ophthalmocarcinoma. Cancer of the eyeball or eyelids.

Ophthalmocele. Exophthalmia.

Ophthalmocholosis. An ocular affection supposed to be due to hepatic disease.

Ophthalmochroites. (L.) The black pigment of the eye.

Ophthalmocopia. Asthenopia, or eye-strain; fatigue of the eyes.

Ophthalmocroites. The black pigment of the eye.

Ophthalmodesmitis. A name for a supposed inflammation of the ocular tendons; an old and now unused synonym of conjunctivitis; also an obsolete term for cyclitis, or inflammation of the ciliary body.

Ophthalmodesmon. An ancient name for the conjunctiva.

Ophthalmodesmoxerosis. Excessive dryness of the conjunctiva; xerophthalmia.

Ophthalmodiagnosis. Diagnosis by the aid of the ophthalmic reaction.

Ophthalmodiaphanoscope. TRANSILLUMINATOR. An instrument for examining the interior and back of the eye by transillumination. See **Diaphanoscopy,** p. 3938, Vol. V of this *Encyclopedia.*

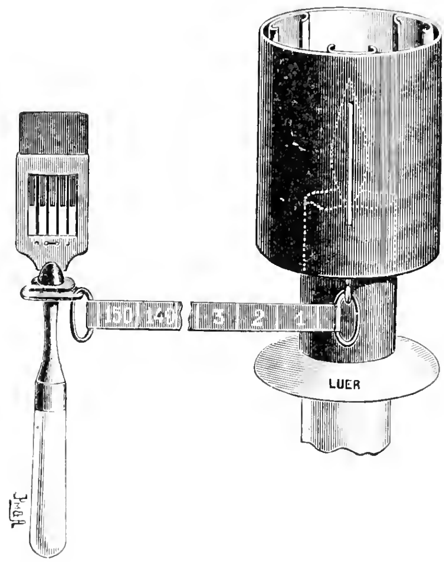
Ophthalmodiastimeter. An instrument for determining the proper distance at which to place lenses before the two eyes.

Ophthalmodonesis. (Obs.) A trembling motion of the eyes; nystagmus.

Ophthalmodynamometer. DYNAMOMETER. OPTOMETER. An instrument for determining the near range, and far point of convergence and, incidentally, of the accommodation. See **Hair-optometer,** p. 5676, Vol. VIII; **Convergence,** p. 3294, Vol. VI; **Accommodometer,** p. 55, Vol. I of this *Encyclopedia.* To the matter under these and similar captions may be added that in the use of the best known device of the kind—*Landolt's ophthalmodynamometer*—the near point of convergence is measured in meter angles (see p. 473, Vol. I of this *Encyclopedia*). An illuminated slit or dot in the cylinder is fixed by the patient (whose refractive errors are corrected) at one meter; then the lighted object is slowly brought near the eye until it is seen double. The amount of convergence is measured on the tape provided. See the figure.

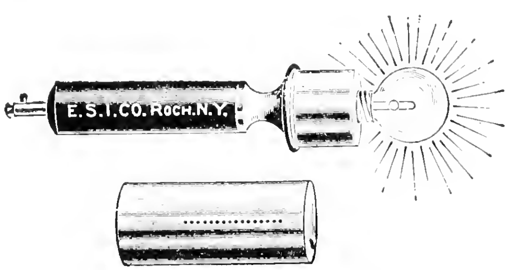
A modification of the Landolt instrument has been devised by C. A.

Wishart. It consists of a metal cylinder, closed at the top, blackened both inside and out, and enclosing a five-volt electric lamp. The cylinder is provided on one side with a vertical line of small openings about



Landolt's Ophthalmodynamometer.

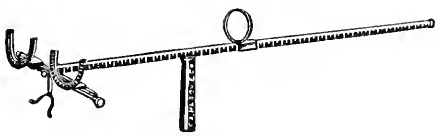
one-third of a millimeter in diameter and placed about the same distance apart. On the other side of the tube is a single opening, two millimeters in diameter. Inside the metal cylinder is a cylinder of white paper. See the cut.



Modified Landolt Ophthalmodynamometer. (Wishart.)

E. J. Gardiner (*Jour. Am. Med. Assocn.*, Apr. 20, 1912) has also described a simple ophthalmodynamometer for "measuring accurately the amplitude of accommodation and convergence, and approximately, the relative range of accommodation and convergence,"

The median bar (see the cut) measures 50 cm. and carries three scales, one in centimeters and millimeters, a second in dioptries-meter angles, and a third, marked "Age in years" (Prince), on which the numbers at the divisions correspond to years. This scale in conjunction with the dioptric scale indicates the amount of accommodation that is normal at different ages from 10 to 50 years. A convenient nose-rest is attached to the proximal end of this bar, and it is also provided with a handle, enabling the patient to hold the appliance in position during the examination. It also carries the object-holder which is so constructed that it can be easily slid back and forth.



An Office Ophthalmodynamometer.

The test-object furnished with the appliance is a Prince card, on the back of which a 2 mm. dot has been stamped for measuring the amplitude of convergence.

The lens-holders are mounted on a graduated cross-bar and can be adapted to the pupillary distance by means of a screw of double rotation. In order to bring the lenses to about 13 mm. from the cornea, the carriers are set back 10 mm., and the rings are pivot mounted so that the plane of the lenses can be adjusted to the visual axis.

For ordinary clinical work, the data furnished by this appliance in combination with the standard trial lenses will suffice without further computation, but if a more accurate measurement of the relative range of accommodation is desired, it may be readily obtained by calculating the exact strength of each lens at its distance from the eye.

Ophthalmodynia. Dolor oculi. Eye-ache. Neuralgia of or pain in the eye. See **Dolor oculi,** p. 4058, Vol. VI of this *Encyclopedia.*

Ophthalmofantôme. (F.) Mask for the practice of ophthalmic operations.

Ophthalmofundoscope. An apparatus for observing the fundus of the eye; an ophthalmoscope.

Ophthalmography. Ophthalmology; a description of the eyes.

Ophthalmohydrorrhea. (L.) A synonym of ophthalmydrorrhea.

Ophthalmol. A proprietary preparation for use locally in granular lids and other eye diseases. According to the owners, it is "a natural product, representing the glandular extract of the fish *Cobitis fossilis.* One part of such extract is digested with 10 parts of pure vegetable

and mineral oil (olive, cotton, almond, vaseline), carefully sterilized. A content of an organic iodine combine is no doubt partly responsible for the curative action."

Ophthalmoleukoscope. An apparatus for testing color-perception by means of colors produced by polarized light.

Ophthalmolith. A stony concretion in the ocular structures or passages.

Ophthalmologic. OPHTHALMOLOGICAL. Pertaining to ophthalmology or to the scientific study of the eye.

Ophthalmologist. One who is versed in or who makes a scientific study of ophthalmology; now preferred to the term oculist.

Ophthalmologists, Blind. Among those ophthalmic surgeons who were wholly or partly blind are **Gimbernat; Harley, George; Hey, William; Javal; Laqueur; Littell, Squier; Pfaff; Quaglino; Ritterich; Wagner; Waldhauer; Watson, Spencer.**—(T. H. S.)

Ophthalmology. That branch of science dealing with the anatomy, physiology, pathology, etc., of the eye.

Ophthalmology, Comparative. See **Comparative ophthalmology.**

Ophthalmology, Domestic. See **Superstitions of ophthalmology.**

Ophthalmology, History of.[1] Some day the history of ophthalmology will be actually written. I shall not attempt to write it, either here or elsewhere. I shall merely endeavor, in this place, to present an outline of this highly intricate, as well as extremely important, subject; to remove the veil which seems to conceal for many the interconnection of its major parts; to paint, as it were, in a kind of miniature which shall have some meaning as a whole, the enormously complicated ophthalmologic panorama that has been unrolling for forty-two hundred years.

I may be permitted, however, to speculate on what a history of ophthalmology ought to be. It ought, as one might almost take for granted, to be a *closely connected* history, a story whose parts are interrelated in numerous ways and even kinds of ways. The *nexus*

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[1] In addition to the obligations acknowledged in the preface to Volume V, of this *Encyclopedia*, I here record my very great indebtedness, in the preparation of the present article, to Dr. Edward Jackson's history of early American ophthalmological societies in Vol. V of his "*Ophthalmic Literature*," also to Dr. Alexander Duane's "*New York Ophthalmological Society*," *op. cit.*, June, 1915, p. 83, and Walsh's "*Thirteenth Greatest of Centuries*," N. Y., 1913.

I am also indebted for much bibliographical assistance, as well as for the loan of many volumes, to Miss Blanch Unterkircher, Librarian, Superior, Wisc., Public Library; Mr. Walter M. Smith, Librarian, University of Wisconsin, Madison, Wisc.; Mr. J. T. Gerould, Librarian, University of Minnesota, Minneapolis, Minn.; Mr. Clement W. Andrews, Librarian, John Crerar Library, Chicago, Ill.; and Dr. C. C. McCulloch, Librarian of the Surgeon General's Office, Washington, D. C.

I have referred to the original documents—"primary" rather than "secondary" authorities—whenever it was reasonably possible so to do.

of the whole should be the most important matter—the evolution of the subject.[2] Then, too, the history of medicine in general should run beside the more particular matter, like a gigantic guide, albeit not too frequently or too extensively consulted. Then, on the other side of that, there should pace, with still more colossal footsteps, the history of the human species. This outermost guide should also be consulted at intervals only. Yet its baldest hints, its slightest reminders, should (when relevant) by no means be ignored—they possess too great a significance for ophthalmology.

Then, too, all the parts of a proper history of ophthalmology should be presented *in precisely the right proportions.* Nothing essential should be omitted, and nothing non-essential should be included. The mistake, especially, should not be made of supposing a thing to be essential merely because the writer happens to be familiar with it. And of all the essential matters (which now we suppose to be included) each part and parcel should receive that just and righteous emphasis which, by its very nature, is its due. And emphasis (I have found by actual experience with critics that it is necessary to say this) should not be measured by line-bulk, or word-bulk, only. A great mistake is to suppose that, if Father ophthalmologist A is twice as important as Father ophthalmologist B, then ophthalmologist A should receive precisely twice the number of pages, or even of lines and of words, which B receives. Emphasis and proportion are not to be measured by yardsticks only. What is said is often more important than the quantity of the saying. Furthermore, whatever is treated of at all should be handled at sufficient length (and no further) to make it clear, whatever that length may be: as a result of which plainly true principle, the nearer we come to the present time, and hence to things which we understand already, the less, as a rule, will be the quantity of explanation which we shall need to receive about it.

In addition to these two qualities—connection and proportion—there is still one more attribute which ought to be included among the chief desiderata for a history of ophthalmology. I refer to the often lacking trait, called "interest." Interest should be both human

[2] Throughout the course of this entire "**History of Ophthalmology,**" I have attempted to escape from the snare of repetition. The present article, however, because of the presence in this *Encyclopedia* of numerous detached biographical sketches and minor historical articles, is something of a twice-told tale, and, by consequence, I have, occasionally, been under the necessity of repeating. Even so, the Editor has thought it worth while that there should be presented an outline story of the rise and development of our science and art, because of the opportunity which such an article affords to exhibit the *interrelations* of the various periods and personages involved—interrelations which, though extremely important, could not by any manner of means have been shown adequately in the scattered biographical sketches and minor historical articles.

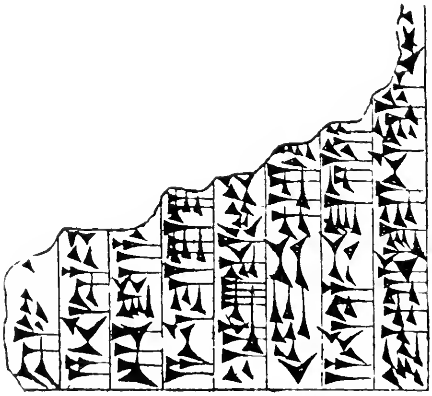
and scientific. The latter arises, I should say, when facts of scientific value are so presented that their value can be seen. The former (which is also of importance in any sort or kind of history) should have its origin in the frankest kind of recognition that a scientist is a man as well as a student of nature.

The story of ophthalmology, like all good stories, or plays, may be divided into five stages, or acts. Act I, The Beginnings. Act II, From Hippocrates until the Middle Ages. Act III, The Middle Ages (including the Byzantine, the Saracenic, and the Western, Middle Ages). Act IV, The Modern Period—Europe. Act V, America.

It is hardly necessary to remind a person who knows but little of ophthalmologic history that a wonderful crisis (precisely as in a drama, and in many novels) arose in the history of our art just about the middle of Act III. And the fact is more than apparent that the "catastrophe" of ophthalmology, the "conclusion" of the story, the "dénouement," is always, like the rainbow's end, a little way beyond us. It is the unattainable, and so we shall just almost, but not quite, reach it. The drama is not played out, and will not be, of course, until the end of time, or at least, of civilization.

I. THE BEGINNINGS.

When did ophthalmology begin? Nobody knows, any more than anybody knows when medicine itself began, or when history began,



An Ancient Babylonian Tablet.

or the tribe of human beings had its origin. It began, however. Some time and some where, like all things finite, it underwent a genesis—perhaps in Asia. And it surely existed "for many a slow-unfolding

age'' before it ''peeped'' within the covers of a book. The earliest mention of it that we know is, oddly enough, found in an ancient work on law, not medicine—The Code of Hammurabi. This, an ancient collection of laws promulgated, enforced, etc., by a king of Babylon-Assyria, called Hammurabi, who ruled about 2250 B. C., contains a considerable number of heads, or sections, which relate to ophthalmology, and (sadly enough) to ophthalmic negligence, or malpractice. Here are all the sections which apply:

''196—If a man destroy the eye of another man, they shall destroy his eye.

''198—If one destroy the eye of a freeman or break the bone of a freeman, he shall pay one mana of silver.

Ancient Babylonian King, Holding Captives by Hooks in Their Lips, and Putting Out One of the Captive's Eyes.

''199—If one destroy the eye of a man's slave or break a bone of a man's slave, he shall pay one-half his price.

''215—If a physician . . . open an abscess (in the eye) of a man with a bronze lancet and save that man's eye, he shall receive ten shekels of silver (as his fee).

''216—If he be a freeman, he shall receive five shekels.

''218—If a physician open an abscess (in the eye) of a man with a bronze lancet and destroy the man's eye, they shall cut off his fingers.

''220—If he open an abscess (in his eye) with a bronze lancet, and destroy his eye, he shall pay silver to the extent of one-half his price.''

Briefly, we may call attention, in the foregoing passage, to these five salient facts: (1) That the absolutely first words in history on

the subject of ophthalmology relate to ophthalmic malpractice—a fact of considerable significance. (2) That, in those days, the "*lex talionis*" (an eye for an eye, etc.) was literally enforced. (3) That a wide distinction was made between ophthalmic malpractice in the case of a slave, or plebeian, and what would otherwise be exactly the same offense in the case of a freeman. (4) That surgical instruments in those days were evidently manufactured from bronze—which goes to show that the Babylonians of that time were not yet out of the bronze age. (5) That the science of ophthalmology was not very far ad-

Ancient Babylonian Priests. (From the Monuments.)

vanced. It was also mixed to the vanishing point with the grossest of superstition and magic—but of that hereafter.

In order to understand the ophthalmology of the ancient Assyrio-Babylonians we shall have to glance at the general physiological and pathological conceptions of the place and time. It was, in a word, believed that the seat of life is the blood, the seat of intellect, the heart. Round this conception of the heart and blood would seem to have circled the entire physiology and pathology of the day. The great blood-factory was the liver. There were two kinds of blood—day-blood and night-blood—or, as we should say, arterial and venous blood. Disease was chiefly begotten by something which acted on the blood. The something, as a rule, was either the inauspicious influence of a heavenly body (for the Assyrio-Babylonians were great astrologers) or else the action of an evil spirit. The practice of medicine and surgery (including ophthalmology) was almost wholly in the

hands of priests. By a necessary consequence the medical practice of the day was, for the most part, theurgy and magic.

In order not to dwell too long upon a theme necessarily monotonous and otherwise somewhat unpleasant, I subjoin a portion of an incantation[3] which may be regarded as typical (it is also somewhat comprehensive) of the manner of treating diseases in the "earliest ashen dawn" of civilization:

INCANTATION.

1 The wicked god, the wicked demon,
the demon of the desert, the demon of the mountain,
the demon of the sea, the demon of the marsh,
the evil genius, the enormous *uruku*,
the bad wind by itself,
the wicked demon which seizes the body, which disturbs the body.
Spirit of the heavens, conjure it! Spirit of the earth, conjure it!

2 The demon who seizes man, the demon who seizes man,
the *Jijim* who works evil, the production of a wicked demon,
Spirit of the heavens, conjure it! Spirit of the earth, conjure it!

3 The consecrated prostitute with the rebellious heart, who abandons the place of prostitution,
the prostitute of the god Anna, who does not do his service,
to the evening of the beginning of the incomplete month,
the sacred slave who fails to go to his place,
who does not lacerate his chest,
who does not slap with his hand,
making his chest resound, completing . . . .[4]
Spirit of the heavens, conjure it! Spirit of the earth, conjure it!

4 That which does not go away, that which is not propitious,
that which grows up, ulcers of a bad kind,
poignant ulcers, enlarged ulcers, excoriated ulcers, ulcers . . . .,
ulcers which spread, malignant ulcers,
Spirit of the heavens, conjure it! Spirit of the earth, conjure it!

5 Disease of the bowels, the disease of the heart, the palpitation of the diseased heart,

[3] From Lenormant, "*Chaldean Magic*" (London, 1877), p. 3.

[4] The leaders, in each case, stand for a word or words which are untranslatable.

disease of the vision, disease of the head, malignant dysentery,
the tumour which swells,
ulceration of the reins, the micturition which wastes,
cruel agony which never ceases,
nightmare.
Spirit of the heavens, conjure it! Spirit of the earth, conjure it!

6 He who forges images,[5] he who bewitches
the malevolent aspect, the evil eye,[6]
the malevolent mouth, the malevolent tongue,
the malevolent lip, the finest sorcery.
Spirit of the heavens, conjure it! Spirit of the earth, conjure it!

But enough of superstition and magic. Here is a pleasanter matter—a letter from an oculist-priest, called Ardi-Nana, to his king, Esarhaddon—concerning a patient in whom the King would seem to have taken a particular interest:

"To the King, my Lord, thy servant Ardi-Nana. May it be peace in the highest degree to the King, my Lord; may Ninip and Gula[7] give cheer of heart and health of body to the King, my Lord. It is extremely well with that poor man whose eyes are diseased. I had applied a dressing to him, it covered his face. Yesterday, at evening, I undid the bandage which held it, I removed the dressing which was upon him. There was pus upon the dressing, as much as the tip of the little finger. Thy gods, if any of them has put his hand to the matter, he has indeed given his order. It is extremely well. Let the heart of the King, my Lord, be cheered. In seven or eight days he will be well."[8]

The letter, though not quite free from superstition and theurgy, is plainly seen to imply a semi-scientific viewpoint. This is at least encouraging, and as much as we ought to expect in the childhood of the world. In "the fulness of the times" and in a land made more favorable to medicine by a long course of philosophy, will appear the great magician of our craft—a magician who cast out magic itself, placing the healing art upon an eternal foundation of observation and experiment.—But of him, the master of masters, the physician of all physicians, we shall speak hereafter at length.

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[5] Here we have the first reference to a custom well known in the middle ages. A waxen figure was made, and as it melted before the fire the person represented by it was supposed similarly to waste away.—Lenormant.

[6] See, in this *Encyclopedia*, **Evil Eye, The,** VI, 4554.

[7] Babylonian gods of healing.

[8] Translation of Dr. C. Johnston, as quoted by C. H. W. Johns, in his "*Babylonian and Assyrian Laws, Contracts and Letters,*" p. 374.

The scene now changes. We pass, in space, from ancient Babylon to ancient Egypt, and, in time, from 2250 B. C. to about B. C. 1650.

The earliest records of ophthalmology in ancient Egypt are in the so-called Brugsch papyrus (*circa* 1550 B. C.) and the papyrus Ebers (*circa* 1650 B. C.).[9] Of these the papyrus Ebers is much the more important. We must, therefore, tell about this document in considerable detail. It was found by Egyptologist Ebers,[10] during the winter of 1872-73, in the possession of a certain Arab, who, in turn, had discovered it between the legs of a common mummy in the necropolis

An Ancient Egyptian Papyrus.

of Thebes. Inasmuch as this was one of the most important of all Egyptian documents, the price demanded for it was extremely high. However, Herr Max Guenther, Privy Councillor of Commerce at Leipzig, a very wealthy person, who just then happened to be sojourning in Thebes, advanced to the rescue, and Ebers became the owner of the document.

So much for the meaning of the "Ebers" portion of the name. It is scarcely necessary here to add that the word "papyrus" refers to

[9] Ancient as are both these hoary papyri, they seem like recent documents when compared with the Code of Hammurabi, which, dating back to the year two thousand two hundred and fifty before Christ, is older than the elder of the Egyptian volumes by fully six hundred years.

[10] See **Ebers, Georg,** in this *Encyclopedia.*

the material on which the book was written. Papyrus consisted, in fact, of strips, or sheets, from a sedge-like plant *(cyperus papyrus),* which strips were rolled on sticks and placed in cylinders for preservation. The English word "paper" is derived from "papyrus," and "volume" from "volumen"—something rolled—referring, of course, to the rolled-up shape of ancient books—which were, indeed, literally "volumes." The papyrus Ebers consisted "of a single strip of the finest yellow-brown papyrus" tightly rolled. It was 30 centimeters wide and a trifle over 20 meters long. The text was divided into 110 columns, each of 21 or 22 lines. The number of each column was placed directly above the middle of the first line thereof. After the fashion of the times, the ink employed for the major portion of the text was black, that, however, for the beginning of each sentence, red. (Whence the English "rubric"—*rubrum* meaning red.)

Ebers, taking the precious volume home with him to Leipsic, there performed the arduous task of translation. He then deposited the almost priceless document in the Library of the University of Leipsic for safe-keeping. There it still remains, although, for ease of exhibition, it has been divided into twenty-nine pieces of different lengths. Each piece lies beneath a heavy plate of very transparent glass, except those pieces which are written upon on both their sides, and these are enclosed between two plates.

The papyrus Ebers which, as above stated, consists of 110 pages, or columns, describes all the diseases (and the remedies therefor) that were known to the Egyptians at the time when the document was written. Eight pages are devoted exclusively to diseases of the eye. The ophthalmic portion of the work, translated by Ebers into German, was published at Leipsic with the title, "*Papyrus Augenkrankheiten.*"[11] Many ocular diseases are named in this early work on ophthalmology, but none is described in detail. Numerous prescriptions are, however, given, and these, of course, are very valuable historically.

Some of the more important ocular diseases and the remedies therefor, as given in this ancient manuscript, are as follows:

1. For "Blood in the Eyes," which meant, probably, either congestion of the conjunctiva or subconjunctival ecchymosis (hyphæma) were used verdigris, antimony, and powdered wood.

2. For "Tear-Eyes" (epiphora) were employed incense, boiled papyrus, acacia gum, antimony and water.

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[11] A complete translation of the papyrus Ebers, made by H. Joachim, was published at Berlin in 1890.

3. For "Dimness of Sight" (cataract, corneal opacities, and possibly other conditions) the Egyptians recommended in the early stages, swamp water; later, compresses of antimony and honey. A favorite prescription was honey mixed with excrement from a child.

4. For "Blear Eyes" (trachoma) equal parts of verdigris and onions were mixed together and laid on. Various sorts of eye-water (collyria) were also employed. Trachoma was then, as now, in Egypt, a wide-spread and terrible curse.

5. For "Pain in the Eye" an ointment was employed consisting of antimony and charcoal.

6. For "Narrowing of the Pupils" frequent poulticing with a solution of saltpeter and ebony-shavings.

7. For "Stone in the Eye" (by which is meant, no doubt, concretions in the Meibomian glands) antimony, vermillion (red lead) plumbagin and natron.

8. For "The White-Becoming" (leucoma and, possibly, cataract) the brain of a tortoise mixed with honey.

9. For "Turning of the Eyes" (strabismus) equal parts of tortoise brain rubbed up with oriental spices.

10. For "Bade" (chemosis) genuine antimony, washed in the milk of a woman who has borne a male child.

11. For "Pus in the Eye," of clay, honey and ricinus leaves, each one ro. (A "ro" = 0.0141 liter.)

12. For "The Mounting of Water in the Eye" (probably cataract) genuine lapis lazuli, verdigris, crocodile dung, frankincense and milk. "Mix these, and apply them to the eyes."

13. For "The Driving away of a Swelling on the Nose" (dacryocystitis). Antimony, powdered wood, myrrh and dried honey. Rub into the eyes for four days. "Take note of this, for it is surely the right application."

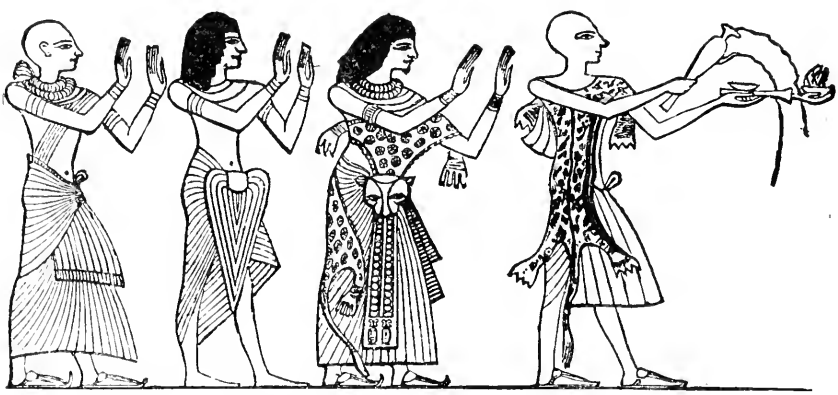
14. For "The Curving of Hairs into the Eye" (trichiasis, distichiasis, entropion) myrrh, lizard-blood and bat-blood. "Pull out the hairs first; then apply this to the eye, in order that it may be rendered sound."

We cannot comprehend the ophthalmology of ancient Egypt without at least a bird's-eye-view of ancient Egyptian medicine in general. Here, then, is the bird's-eye-view—the bird flying rapidly. Medicine, in those far distant days in Egypt, was taught, together with all the other learning of the age, in the temple schools: Sais, On, Memphis, Thebes. The teaching was clinical, as well as didactic, and patients were seen both in the temples and in homes about the city.

At first the priests were doctors and the doctors priests: there was

no distinction. At an early date, however, a separation occurred, and physicians, surgeons, and exorcisers formed entirely distinct classes in the community. Later still (i. e., in the period of Egyptian medical decay) specialists appeared—dentists, oculists, aurists, etc. Of these we shall speak hereafter.

Anatomy, in the golden age of Egyptian medicine, was little, if at all, above the level which had been attained by that extremely unappreciated subject in Assyria. This is a rather remarkable fact when we stop to consider the great antiquity and universal practice of embalm-

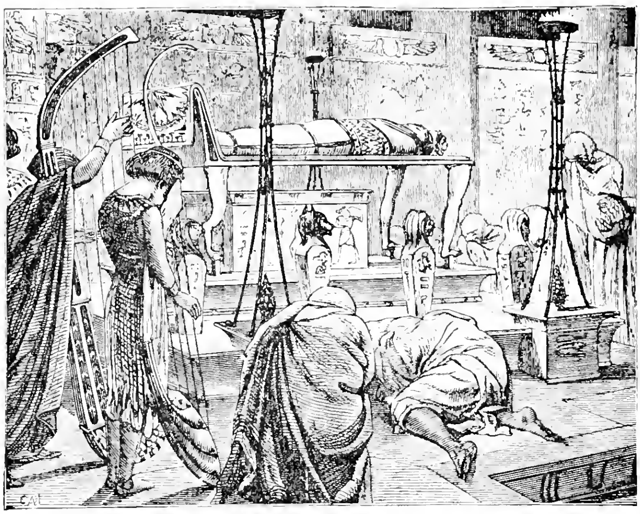


Ancient Egyptian Priests. (From an Old Woodcut.)

ing in ancient Egypt. Good, bad, and indifferent, rich and poor, learned and unlearned, everybody, in Egypt, had to be embalmed. Embalming was, in fact, regarded by the ancient Egyptians as an essential portion of religion. The preservation of the body was a *sine qua non* to the resurrection of the individual from the dead. Now, there were three grades of embalming, of greater or less expense, and, in the more expensive variety, it was customary to "extract the brain from the nostrils by a curved iron probe, and also to remove the intestines through an incision in the side of the belly." One would naturally suppose that, under these circumstances, the Egyptians would soon have resorted to dissection for the purpose of ascertaining the structure of the human body. This, however, they did not do, but remained in comparative ignorance of human anatomy, until the Greeks, who, having in the seventh century B. C. taken home with them from Egypt their first genuinely scientific notions of medicine, afterward returned the loan with enormous scientific usury. We may say, in a word, that Egyptian (by which we mean Egyptian, not the later Greco-Egyptian) medicine knew nothing whatever of anatomy, save

a very tiny bit, acquired, as it were incidentally, during the slaughter of animals for sacrifice and food.

Physiology, almost entirely, however, of a speculative order, was developed to a somewhat higher degree. The central point of Egyptian physiology was the great importance attached to respiration. It will be recalled that, when discussing Sumerian, or Babylonian, medicine, we saw how little attention was paid by the Babylonians to the lungs and respiration. The Babylonians thought chiefly about the heart and



Embalming the Body of an Egyptian King. (From an Old Woodcut.)

blood. It will also be recalled that they distinguished blood as being of two varieties—day-blood and night-blood, or, in modern parlance, venous blood and arterial. Now, the Egyptians distinguished air as being of two kinds—air of life and air of death. Probably these referred to the air of inspiration and that of expiration; if so, the terms were not so very incorrect. The arteries, in the dead (the Egyptians did not practise vivisection) were always found to be empty. This meant, of course, to those people, that these little tubes were conveyors of air to the different parts of the body—a conception which, as we shall see hereafter, did not pass away till near the time of Harvey, who, as is known (adding merely one or two links to the chain of former knowledge), discovered (in 1616) the circulation of the blood. To the Egyptians the blood-vessels were the veins. The blood itself, they thought, was somehow concocted in the heart and the stomach—not in the liver, as the Babylonians had believed.

As to pathology, some cases of some diseases were supposed to be due to magical influences, many other cases of many other diseases, to be the work of the gods. To a great extent, however, the Egyptians did really attempt a rational pathogenesis. They regarded nearly all diseases as begotten either by overeating or by worms. Animal parasites, in fact, were (as they still are) extremely common in Egypt;

I-em-hetep, the Egyptian God of Medicine.

besides, in hot countries, how readily one can make one's self sick by overeating.

As to methods of diagnosis, the Egyptian doctor practised inspection, palpation, auscultation, percussion and even examination of the urine. All these measures, of course, were rudimentary.

Egyptian medicine (as might have been gathered from our discussion of the papyrus Ebers) bulks most largely in the matter of therapeutics. To the ancient Egyptians, in fact, we of today are indebted for some of our most reliable remedies. On the other hand, there was mingled with rational therapeusis the grossest of superstition and magic. Strange to say, the earlier the manuscript, the more rational the therapeusis; the later the manuscript the more magical and theurgical. Thus Egyptian medicine, at least in historical times,

seemed, as the immortal Micawber would say, to have progressed in a retrograde direction. Sometimes drugs were only to be prepared while certain magical sentences were uttered. Again, magic was the whole of the matter. Temple-sleep, too, as among the Assyrians, was very often resorted to. However, in the golden age of Egyptian medicine there was very much that was wholly, or almost wholly, rational. Thus, emetics, purgatives, and enemata were employed. In fact, the enema seems to have been discovered in Egypt. Blood-letting was common—as common, in fact, as it was in the United States of America some fifty or sixty years ago. In fact neither the memory nor the records of man run back to a time when it was not regarded as wholesome to part with a little blood—particularly in peaceful times. Diuretics, diaphoretics and sternutatories were employed to some extent. Then, too, they possessed and frequently employed powders, draughts, gargles, inhalations, fumigations, suppositories, plasters, salves, and poultices. Particular medicaments very commonly employed were: onions, leeks and beans, castor-oil, pomegranate, copper salts, oxymel of squills, hemlock and opium. Certainly a very respectable list, and one which, as to some of its constituents at least, we should very much dislike to lose from our present pharmacopeia.

Concerning Egyptian surgery we know but little. Circumcision and castration the Egyptians undoubtedly performed. In fact, the upper classes were universally circumcized, men and women. It seems, however, that amputations were unknown to the Egyptians. In this respect, they had, apparently, lapsed behind certain of the lower animals. The Egyptians probably were better surgeons, however, on the whole, than the texts would seem to indicate, for they possessed knives, hooks, forceps, needles and probes. They also understood, in a way, the use of the cautery. Even the texts disclose the fact that they had some knowledge of the surgery relating to tumors and abscesses. Thus, the papyrus Ebers: "When thou findest a purulent swelling with the apex elevated, sharply defined and of a rounded form, then sayest thou, 'It is a purulent tumor which is growing in the flesh . . . I must treat the disease with the knife.'

"When thou findest a growth upon the throat of a patient . . . containing matter . . . and thou findest its top raised like a wart, know that the matter moves within it.

"When thou findest a fatty growth in the neck, and findest it like an abscess of the flesh and soft to the fingers, then sayest thou, 'He has a fatty growth on his neck. I will treat the disease with a knife, paying heed to the vessels.'

"When thou findest a tumor of the flesh in a particular part of a

person's body, and findest it like skin upon his flesh, it being moist, moving with the fingers except they be still, the movement being thus due to the fingers, it is a tumor of the flesh; then sayest thou, 'I shall treat the disease by trying to cure it with fire.' "

Obstetrics and gynecology were practised by women only. Four midwives always officiated, and delivery was accomplished on a stool.

It was, however, in hygiene that the Egyptians contributed most toward the advancement of medicine. The danger of overeating was thoroughly appreciated, even by the common people, and to such an extent that a corpulent Egyptian was practically unknown. Then they were very careful as to what they ate. They had, for instance, an excellent system of meat inspection, they possessed innumerable rules, for the most part sensible, relating to the bath, to clothing, to sexual intercourse, etc.[12]

In the later days of Egyptian medicine and surgery, came abundant specialization. Thus the well-known passage of Herodotus, relating to what he had learned personally in Egypt concerning matters medical as they there existed in his day—i. e., five centuries B. C.: "The art of medicine is thus divided among them: each physician applies himself to one disease only, and not more. All places abound in physicians; some physicians are for the eyes, others for the head, others for the teeth, others for the parts about the belly, and others for internal disorders." This high degree of specialism, however, was characteristic only of the period of decay in Egyptian medicine. With it, strangely enough, came in the grossest superstition and most idiotic magic.

The grossest superstition and most idiotic magic, in fact, prevailed over all the world. Thus, in Palestine, to remove a boil, one said "Baz, Baziyah, Mas, Masiyah, Kas, Kasiyah, Sharlai and Amarlai—ye angels that came from the land of Sodom to heal painful boils! Let the color become more red, let it not farther spread, let its seed be absorbed in the belly. As a mule does not propagate itself, so let not this evil propagate itself in the body of M., the son of M." At a slightly later date, in Rome, Marcius Porcius Cato, the Censor, who also practised medicine, sang, whenever he attempted to reduce a dislocation, this exceedingly rational song: "Huat, hanat, ista, pista sista damniato damnaustra." And yet at least a portion of the world (and that no unimportant portion) was ready for a change. That portion of the world, as one might say, had begun to know of its superstitious fetters, to feel their painful chafing, and to wish them

[12] The relation of all these matters to the eye can easily be understood.

gone. It had, in fact, begun to speculate, to philosophize—to think. "The fulness of the times" had come. And so the curtain will now arise on the final scene of the first of the acts in the great ophthalmologic drama—a scene in which the star performance will be played by Hippocrates of Larissa, also known as Hippocrates the Second, and Hippocrates the Great. After the time of Hippocrates, the course of ophthalmology can never be the same again, even to the very moment in which I write.

Our consideration of Hippocrates will naturally be divided into two chief parts: (A) Hippocrates as man and as general physician.[13] (B) Hippocrates as ophthalmologist.

A. HIPPOCRATES AS MAN AND AS GENERAL PHYSICIAN.

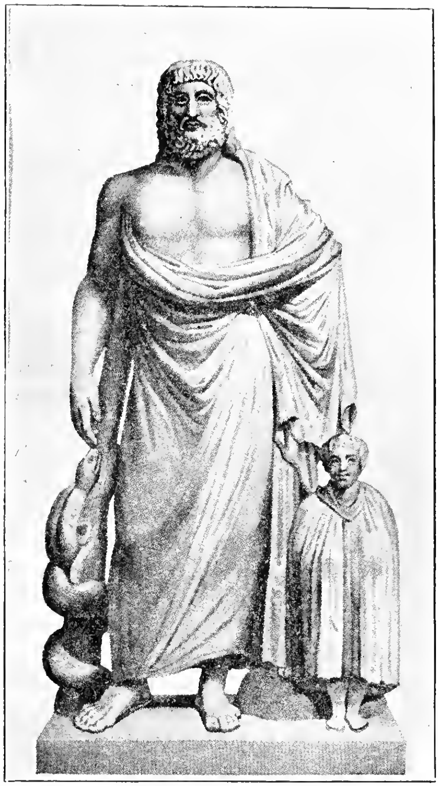
To comprehend Hippocrates the man and general practitioner of medicine, we shall have to consider the history of Greek medicine (in

Homer.

a nutshell of course) from a time when the Trojan war was still raging, down to the age of the Father of Medicine himself. In the Iliad we read of numerous wounds received by various heroes during the war, and the treatment that was given for such injuries. When a dart could not be withdrawn by simple traction, the wound was widened, or a counter-wound was made, so that the dart might be pulled,

13 It is simply impossible to understand the ophthalmology of Hippocrates (or indeed of any ancient writer) without some comprehension of Hippocratic medicine in general.

or possibly both pulled and pushed, on through. Powders and poultices were applied both to arrest hemorrhage and to alleviate pain. Opium, too, was probably known by the Greeks in those days. The Egyptians had known about it earlier. A tonic for the wounded was compounded of wine, flour, honey, onions, and cheese made from goat's milk. Iron rust, hellebore, and sugar baths also belonged to the

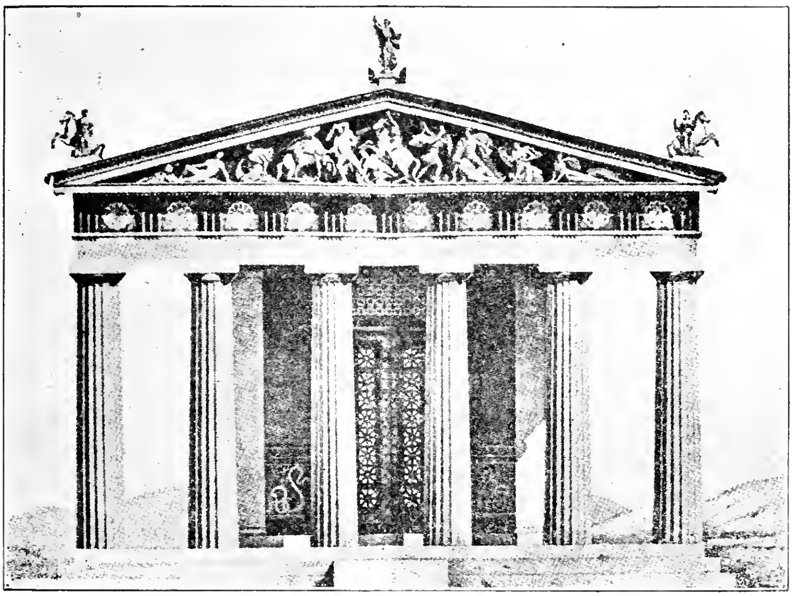


Aesculapius. (From the Marble Statue in the Louvre.)

pharmacopeia of Homeric times. Venesection was old, even in those old days. Every hero seems to have been in some sort a doctor, yet professional physicians did exist, under the name of polypharmakoi.

Homeric medicine was, at first, somewhat free from invocation and other forms of magic. Divine healers, however—gods who would, under certain circumstances, condescend to help the sick—we read about in Homer and writers of a somewhat later day, and that to no very small extent. Leclerc computes that, in Homeric and pre-Homeric days, there were thirty gods or demi-gods who had invented

or practised one or another branch of medicine. Of these Melampus was one of the earliest. Being a shepherd, he had noted the purgative effect of white hellebore on goats. The daughters of Proetus, King of Argus, having become insane, Melampus gave them milk in which white hellebore had been boiled, and thus produced a cure. Next came Chiron, the centaur, half man and half horse, the preceptor of Asclepius, or, as we of today will have it, after the Romans, Æsculapius. Æsculapius was the greatest of all the gods of healing. He was said to



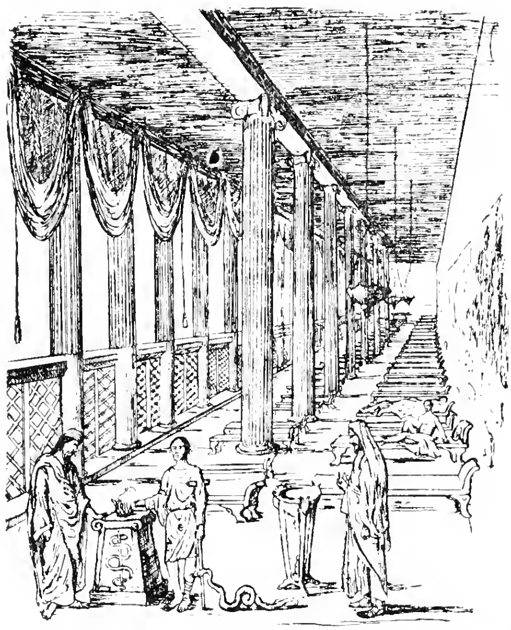
Restoration of East End of Temple of Asklepios. (Defrasse.)

be the son of Apollo by the nymph Coronis. Temples were erected to Æsculapius, ordinarily in the neighborhood of thermal springs and among shady groves, always, of course, in some salubrious situation. Regular corps of priests officiated in these temples, and these priests formed schools for the giving of medical and surgical instruction. Two sons of Æsculapius enjoyed a special reputation in surgery; these were Machaon and Podalirius. It is said that Æsculapius himself was finally destroyed by Pluto, the god of the infernal regions, out of fear that, if the god of healing were allowed to continue his work on earth, the time-honored march from the fields of the living to the regions of the dead would be entirely stopped.

After the death of Æsculapius, his temples became a sort of hospitals for the sick, for the patients slept and ate in these temples,

or at least within their precincts, in a building called the "Abaton." The men slept in one part of this building, the women in another. As the patients got better, they removed to the hostels near by. When the crowd of supplicants was very large, temporary structures of wood, or even tents, were erected. Some of the sick lodged in neighboring towns.

The patient, on arriving, bathed in the sacred fountain and offered sacrifices. A suitable regimen was enforced, and salutary herbs and



Restoration of the Interior of the Abaton at Epidauros. Patient Sacrificing and Having Injured Leg Licked by the Sacred Serpent. (From Caton's "*The Temples and Ritual of Asklepios.*")

minerals were administered. Great benefit was also supposed to be secured by the mere sleeping in the temples; and, at times, the god appeared in dreams and instructed the sufferer more or less fully concerning the cause and cure of his affliction.[14] The priests were accused, on numerous occasions, of practising fraud in connection with these dreams. It was said, for example, that some of these sacerdotal personages were not entirely above personation of the god, entering for this purpose the room in which the patient lay sleeping, the sick

[14] For the history of individual ophthalmic cases in connection with the so-called "temple-medicine," see, in this *Encyclopedia*, **A, Æschinas, Alketas, Ambrosia, Hermon of Thasos, Thyson of Hermione.**

one having been rendered highly suggestible beforehand by long-continued abstinence from food and by the administration of drugs like opium. Acoustic tricks are said to have been resorted to, whereby it was made to seem that the voice of the deity was speaking in the room. Thick, yellow snakes, too, non-poisonous but highly impressive to the imagination, were kept in the temples, and allowed to glide about the sleeping apartments in the night. Æsculapius, we may add, was supposed, whenever he made himself perceptible by mortal eyes, to take, as a rule, the form of a serpent. Patients made offerings of sacrificial

Votive Tablet Representing a Pair of Eyes, with the Inscription, "Philematin Dedicated (this) as a Votive Offering." (British Museum. Kershaw.)

cakes to these serpents, as a matter of routine. The dog, as well as the snake, was sacred to Æsculapius, or Asklepios, and temple dogs and temple serpents alike, as they ran about the rooms, would stop and lick the sores of the patients—as, in fact, they had been trained by the priests to do. For a still further stimulus to the patients' imagination, thousands of votive offerings were kept hung upon the walls of the temples, all reciting the most remarkable cures which had been effected in or upon the persons of the givers of these offerings. Here is the inscription on one votive tablet: "Julian vomited blood, and appeared lost beyond recovering. The oracle orders him to take the pine-seeds from the altar, which they had three days mingled with honey. He did so. and was cured. Having solemnly thanked the god, he went away."

The most celebrated of the temples of Asklepios were: that at Athens

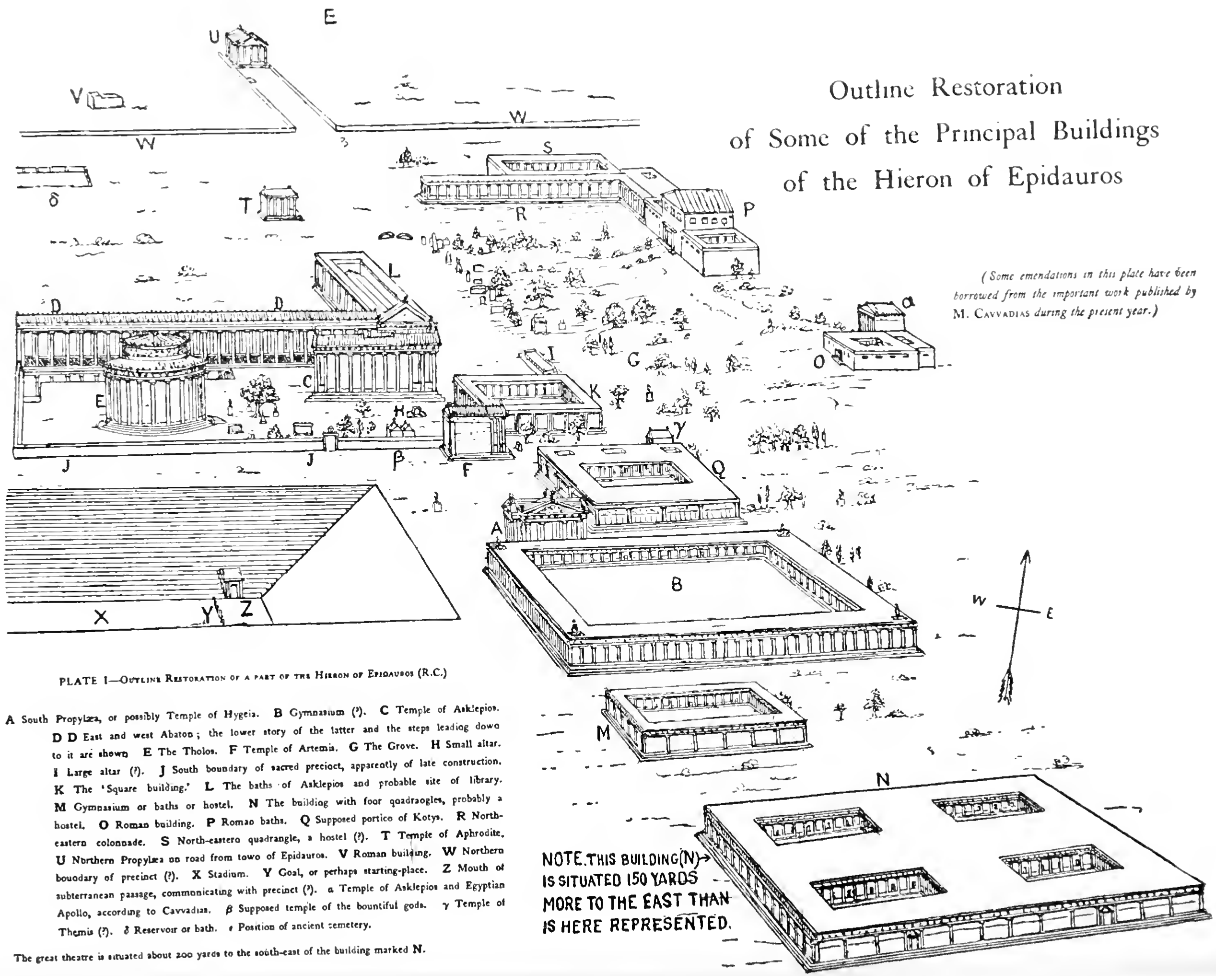


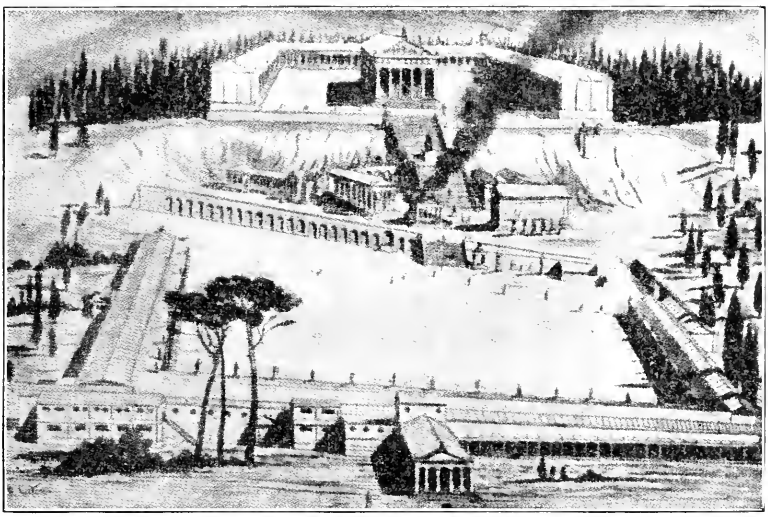
PLATE I—Outline Restoration of a part of the Hieron of Epidauros (R.C.)

A South Propylæa, or possibly Temple of Hygeia. **B** Gymnasium (?). **C** Temple of Asklepios. **D D** East and west Abaton; the lower story of the latter and the steps leading down to it are shown. **E** The Tholos. **F** Temple of Artemis. **G** The Grove. **H** Small altar. **I** Large altar (?). **J** South boundary of sacred precinct, apparently of late construction. **K** The 'Square building.' **L** The baths of Asklepios and probable site of library. **M** Gymnasium or baths or hostel. **N** The building with four quadrangles, probably a hostel. **O** Roman building. **P** Roman baths. **Q** Supposed portico of Kotys. **R** North-eastern colonnade. **S** North-eastern quadrangle, a hostel (?). **T** Temple of Aphrodite. **U** Northern Propylæa on road from town of Epidauros. **V** Roman building. **W** Northern boundary of precinct (?). **X** Stadium. **Y** Goal, or perhaps starting-place. **Z** Mouth of subterranean passage, communicating with precinct (?). α Temple of Asklepios and Egyptian Apollo, according to Cavvadias. β Supposed temple of the bountiful gods. γ Temple of Themis (?). δ Reservoir or bath. ε Position of ancient cemetery.

The great theatre is situated about 200 yards to the south-east of the building marked **N**.

called the Asclepieion and that at Epidauros, called the Hieron. There exists but little information in Greek literature concerning these temples, and the most of our knowledge concerning them is the result of excavations made by the Greek, German and French schools of archeologists at the two chief sites above mentioned. The latest account of these old Greek temples of healing and medical instruction is that of Richard Caton, in a little book called "*The Temples and Ritual of Asklepios.*" An illustration of the "Hieron," as it was called, at Epidauros, showing the temple of Asklepios (or Æsculapius) and various ancillary structures, is shown in the accompanying illustration.

Some of the priests in the temples of Æsculapius were called Asclepiades, sons of Æsculapius.



The Asclepian Temple at Cos: The School Which Hippocrates Attended, and Which Was, Perhaps, His Birthplace.

These claimed actual physical descent from the god, and, after a time, for some reason, they severed their relations with the rest of the Æsculapian priesthood and became independent physicians. Side by side with these, were a multitude of other independent practitioners, such as had always existed, even from pre-Homeric times. Thus, before the days of the greatest Greek of all—Hippocrates—there had come to be in Greece three sorts of physicians: (1) The priests in the temples of Æsculapius (2) The Asclepiadæ, no longer closely connected with the temples, but claiming descent from the god, and, finally (3) Wholly independent physicians in whose history there had been no temple connection whatever. The

temple-physicians, of course, had their strict rule of membership; the Asclepiadæ admitted to their ranks those only who possessed the proper ancestry (this, at least, was, in the beginning, the case); and, finally, the body of nondescripts was open to whosoever desired to unite therewith. Women, however, could not practise medicine, and slaves could treat slaves only. There were state physicians who for a fixed salary attended the poor, supervised matters of public sanitation (hygiene) and appeared as expert witnesses before the courts. There were also military and naval physicians and surgeons, and physicians to the courts of kings and princes.

The Asclepiadæ and the other independent doctors treated patients either in their (the physicians') own homes, or in the patients' homes, or in the so-called "medical homes" (iatreia, iatrikâ ergastéria). These medical homes were not greatly dissimilar to the hospitals of today. Like modern hospitals, they were supported in some instances by the physicians themselves, in others, by the community, which, by the way, levied a special tax therefor. In these medical homes were bedrooms and also operating rooms equipped with instruments and appliances. Students stood about, looked on, and asked questions. The master surgeon would sometimes condescend to lecture. When the matter is considered externally only, it would seem that rational medicine was evolving rather properly in Greece in the century before Hippocrates.

Rational medicine, however, was still greatly hampered in Greece. It made most progress, as might have been expected, in the parts that came most freely under the influences of Mesopotamia and of Egypt. Those places which came particularly under Egyptian influence were Cyrene, Rhodes, Cnidos, and Cos, and at each of these places was a school. Records concerning Cyrene are scanty, however, and the school at Rhodes was, for some reason, short-lived.

The schools at Cnidos and at Cos, however, prospered and became great rivals. Each claimed to have the larger number of students, to work the more astonishing cures, to possess the more celebrated professors. The physicians in the schools of Cnidos and of Cos were neither the priests nor the wholly independents, but the so-called Asclepiadæ, of whom we have previously spoken—that class of physicians, namely, who (originally, at least) had claimed descent from Æsculapius, but who, latterly, had admitted to their body such strangers as were deemed to be qualified to practise medicine. It will be recalled, too, that the Asclepiadæ had once been priests in the Æsculapian temples, but had ceased to be connected with such institutions, except perhaps in an incidental way. There are two note-

worthy facts about these Asclepiadæ that can scarcely be too much insisted upon: 1st, these physicians were rather inclined to be rational physicians (i. e., they were unconnected with the superstitious and sometimes fraudulent practices of the temple-priests) and 2d, they were broadly qualified men. for they did not admit to their body any of the great mass of the independent, and for the most part illiterate,

Hippocrates, the Father of Medicine, and, Therefore, of Ophthalmology.

physicians of the country. From these Asclepiadæ, who at least endeavored to keep themselves free from fraud on the one hand, and, on the other, from ignorance, it was that modern medicine is said by some to have had its origin. At all events, it was the Asclepiadæ —the John the Baptists of scientific medicine—who chiefly prepared the way for the greatest of all physicians of any clime and of any time—Hippocrates.[15]

[15] In fact, the so-called "Hippocratic oath"—the "father" of our modern medical ethics—was in use before the Father of Medicine himself appeared upon the scene of human affairs.

Hippocrates was born, 460 A. D., in the tiny island of Cos, that island whose school—the Coan school—was already one of the two great rival medical colleges. Some say that he was born in the Asclepian temple on that island. He was, appropriately enough, the son of an Asclepiad, Heracleides. He was said to have been descended, through the father, from Asclepius; through his mother, a midwife called Phaenarete, from Hercules. A rather scientific, as well as divine, ancestry! His earliest instruction in medicine he is said to have received from his father, and this education we feel pretty sure was strictly according to the doctrines of the Coan school of medicine. Somewhat later, however, he came beneath the influence of a teacher from the other of the two great rival colleges—the Cnidian. To broaden himself still further, Hippocrates journeyed throughout Hellas, learning all the different remedies, acquiring all the different doctrines. Tradition has it that he visited also Scythia, Asia Minor, Egypt and Libya. Then he returned to Hellas, to the island of Cos, to his own and his father's school.

Hippocrates lived in the golden age of his people. Let us think for a moment of precisely what that means. The golden age of Greece! The age of Pericles, the statesman; of Socrates, the philosopher; Thucydides, the historian. Sophocles and Euripides, in those days, were writing plays that never were to perish. Pheidias and Praxiteles were liberating, from the stone, forms of more than earthly beauty, figures which, they dreamed, and not without reason, were like unto the gods themselves. Zeuxis and Parrhasius, furthermore, were painting pictures long since lost to human eyes, but such, perchance, in many respects, as human orbs will never behold again this side Elysium. Such were the days in which lived Hippocrates, the Father of Medicine. Is it matter for wonder that, in those days, when the gods seemed ever near to men, the divinest art of all—the art that cools fever, that dispels pain, that often gives back life itself—is it matter for wonder that this art, in those days, should have blossomed and borne fruit?

Now, when we think of Hippocrates, we think, as a rule, of some man who wrote the Hippocratic writings. That is a purely mythical, at least a merely supposititious, personage. No one man wrote, or probably could have written, the entire body of the writings which have been attributed to Hippocrates and which are known as the Corpus Hippocraticum. Many of these books were composed, probably, long before the Father of Modern Medicine was born. Let us recall, in this connection, the Hippocratic oath, which, as we said a little while ago, was in use some time before the Hippocratic era.

Then, too, others of his alleged works were written long after his shade had gone to join his very divine ancestors. To render confusion worse confounded, there were numerous physicians *after* the time of the Father of Medicine who bore the same distinguished name. Five of these were lineally descended from Hippocrates the Great. There was also one Hippocrates *before* Hippocrates the Great. There are numerous books which bear the name of Hippocrates. How many? Some say forty-two, others fifty-three, still others seventy-two, while still other writers give still other numbers. How many of these books were written by Hippocrates the Great? About six. Only six, but the spirit which fills these books is that of modern medicine.

Now, before we proceed to discuss the Hippocratic writings, to investigate somewhat their truly wonderful, their almost marvellous scientific ideas, we shall have to review (very briefly of course) the rise and evolution of that useful, as well as beautiful, fabric known as Greek philosophy. This is a matter which is usually regarded as a kind of delicate spider's web, woven by the Greek imagination in a vain attempt to figure for itself the nature of the universe, the secrets of the unknowable. And so to a certain extent it is. For the Greek philosophers did not investigate or experiment, but merely speculated. Nevertheless, the results were so useful that, without Greek philosophy, or some sort or kind of equivalent therefor, this world could never have known of Hippocratic medicine or modern ophthalmology. Greek philosophy was the liberator of the human intellect from the tyranny of superstition and magic. Moreover, Greek philosophy did not wholly concern itself with the unknowable; it dealt also (though of course by ancient methods) with the relations of man-to-man—ethics—and also with the various manifestations of the physical world, or, as we say today, with natural science.

Greece received the germs of philosophy chiefly from Egypt, just as she received also from that country the germs of medicine. Some of the philosophic seed, it is true, came from India, and, it is thought, a little from China. Whencesoever it came, that seed fell on rich ground in the land of Thales, Socrates, Plato and Aristotle.

Greek philosophy began with Thales, of Miletus, a pupil of certain Egyptian priests, about 600 B. C. Thales founded the so-called Ionic school, which was, accordingly, the first school of Greek philosophy. His fundamental doctrine was this: Water is the original source of all things. He raised many questions as to the existence, laws, and purposes of the universe. Thales seems to have been a man of purely theoretical character, yet by founding Greek philosophy, he gave to the intellect of ancient Greece an almost magical stimulant.

A contemporary of Thales was Anaximander. He was of rather a more practical turn than Thales: for example, he introduced among his countrymen the sun-dial, from Babylonia. He also constructed various maps and charts. Nevertheless, he had also the theoretical turn. According to his views there was one original substance, of some sort. And "from this," said he, "the elementary contraries, warm and cold, moist and dry, are first separated in such manner that homogeneous elements are brought together; through an eternal motion there arise, as condensations of air, innumerable worlds, heavenly divinities, in the center of which rests the earth, a cylinder in form and unmoved because of its equal remoteness from all points in the celestial sphere." Now, concerning the "elementary contraries," of which this philosopher speaks, we shall have occasion to refer a little later, when discussing the so-called humoral pathology of Hippocrates, together with its bearing on ophthalmology.

A pupil of Anaximander was Anaximenes. According to Anaximenes the air (not water) was the principle from which all other things had proceeded. The other elements—fire, wind, clouds, water and earth—had proceeded from pre-existent air by condensation and rarefaction. Diogenes of Apollonia was at one with Anaximenes as to these particular teachings.

The next great philosopher of the Ionic school was Heraclitus. According to him, the underlying principle of all things is not water or air, but fire. Fire would seem, under proper circumstances, to constitute life itself. Now I think you will notice that there has really been a little actual progress in the course of the Ionic philosophy.

Next after the Ionic school came the Italic school—which, speaking strictly, was not a school of Greece, but of south Italy. However, it arose and expanded in the Greek colonies which had settled in that region. The first of this school, both in time and in intellect, was Pythagoras, who flourished in the fifth century. He lived for the most part on the island of Samos, but travelled extensively in Egypt and Babylonia—those twin cradles (if cradles can ever be twins) of history and civilization. He founded a school of very peculiar character which was attended by a large body of students. These students held their properties in common, were strictly classified into learners, mathematicians and philosophers, and were subject to a rule imposing upon them absolute silence for a considerable period of years.

Pythagoras got almost entirely out of touch with the physical world of fact, so theoretic was his nature. He believed that the universe was founded on number. Unity, or monad, was the beginning of all things—spirit, God. Duad, or the number two, was the world of

matter. All tangible existences are formed by the mere combination of the odd and the even numbers in various sorts of ways. He had considerable to say about matters medical—recommended healthful food and exercise, employed salves and poultices but condemned surgery.

Medically, we have to regard Pythagoras as a sort of Christian scientist, though totally devoid of Christianity (which was yet to come) and really possessing just a little science. He was a theorist, a dreamer of pleasant dreams. However, he had a considerable influence, as we shall see, on Hippocrates.

A student of Pythagoras, one Alcmaeon of Crotona, introduced the study of comparative anatomy, and seems to have been a remorseless vivisector, even in those days which knew not anesthesia. He was the first to perform abdominal section. In the cadaver, he noted the difference between the "empty" veins (i. e., the arteries) and those containing blood, to which we of today also apply the name of "veins." He taught that sex was determined by the predominance of the male or the female element. He believed, also, that the head of a fetus was the first part formed, this in order that the mouth might gather nourishment from the amniotic fluid. He made some real discoveries. For example, he discovered the optic nerves and the Eustachian tubes—these latter long before the time of Eustachius. The Greek intellect, having now been aroused by speculation, by philosophy, seemed to be doing a little more than spinning cobwebs against impenetrable stone walls. It was learning to deal with the knowable and the actual. The medicine of the Asclepiadæ and the speculation of the philosophers, were alike preparing the way for Hippocrates.

Then there was another important school of philosophy before the time of Hippocrates—the Eleatic, whose founder was Xenophanes. Parmenides and Zeno were noted members of this school. The greatest, however, were Leucippus and Democritus. These two men were strict materialists and founded the so-called "physical" school of philosophy. They explained the existence of the universe by supposing the pre-existence and indestructibility of atoms—particles invisible by reason of their smallness, falling, ever falling, through limitless space, and by their accidental contact creating the various objects that exist, by their separation producing the destruction of those objects. The "atoms" were "seeds of all things." It is hardly necessary to add that the truth of some of this old atomic theory has been actually demonstrated by modern chemistry and physics.

And now we come to the greatest of all philosophers—Socrates. This man was a contemporary, and is said to have been a friend, of

Hippocrates. At all events he exercised upon the Father of Medicine a deep and permanent influence.

This distinguished Athenian was born 469 B. C. He was at first a sculptor, later a student of philosophy. A man of peculiar, almost repulsive, personal appearance, he charmed with the warmth of his heart and with the magic of his intellect the cultured people of his day—perhaps we had better say of all days. He is declared to have invented the inductive method of reasoning. In a limited sense he did. Moreover, his teachings and his life were, in general, so pure, so almost perfect, that, by many modern writers, he has been compared in these respects with Jesus. Alcibiades said to him: "When we hear Pericles, or any other accomplished orator, deliver a discourse, no one, as it were, cares anything about it. But when anyone hears you, or even your words related by another, though ever so rude and unskilled a speaker, be that person a woman, man, or child, we are struck and retained, as it were, by the discourse clinging to our minds." Socrates never opened a school, or delivered public lectures. He merely went about in the public places of Athens, in the agora, the gymnasia the shops, seldom directly teaching, but always attempting to stimulate and arouse the minds of those who heard him. He rejected wholly the physical speculations of his predecessors and used as a point of departure for his teachings the subjective thoughts and opinions of men. His purpose was wholly ethical and practical—to deduce from human intelligence "an objective rule of practical life." Here one can see the origin of the attitude which Hippocrates took toward the healing art. Discarding, for the most part, fine-spun theory, the Father of Medicine sought always some practical object—the alleviation of human suffering. He clung to facts and to induction, and these he impressed into the practical service of man-

Socrates. (Vatican.)

kind. Socrates, desiring to cure diseased minds, established ethics; Hippocrates, wishing to cure men's physical infirmities, founded practical, scientific, modern medicine. As Socrates interrogated continually the people with whom he came in contact, so Hippocrates was a constant observer, or interrogator, of disease. He did not attempt to think out what disease might, could, would, or should be, or how it must appear to demons or to gods; but he looked and saw (or attempted to see) precisely what the phenomena of disease actually are, and (as well as he could for his day) how and to what extent it might be abolished from men. He possessed the inquisitive senses of a child, the brain of a man of science, and the heart of a philanthropist.

We are now, I think, in a position to set aside the philosophical and scientific preparation of the world for the "Father of Modern Medicine," and to consider in some detail the Hippocratic writings.

We said, a short time back, that Hippocrates the Great was not really the author of all the writings which have been attributed to him. In fact, the Hippocratic collection was compiled and edited about 300 B. C., in the medical era, that is to say, which immediately followed upon the era of Hippocrates—the so-called Alexandrian era. And the work of compiling and editing was done in the city of Alexandria under the supervision of Ptolemy Soter. Even in that day doubt existed as to which of the writings of Hippocrates were genuine and which were not. However, if much of the spurious was admitted, little that was genuine, probably, was excluded. We are therefore thankful for the Corpus Hippocraticum, as this great first body of scientific medicine has descended to our times. Compare it with the papyrus Ebers, for example, and note the difference. Even the spurious books are, in many instances, extremely valuable.

First as to *anatomy*. In the Hippocratic writings we find but little that is accurate on this subject, and yet there is something of value, something scientific. All the anatomical knowledge which the great physician possessed was the kind derivable from the slaughtering, the sacrifice, and the occasional dissection of animals. The human body, dead, was held in great respect in those days. Numerous anatomical errors are therefore discoverable in his works which are plainly owing to the differences which exist between the bodies of animals and the bodies of men. Thus, Hippocrates supposes that the human uterus is two-horned. Human osteology and syndesmology he pretty well comprehends. He gives an excellent description of some of the bones and even of the joints, especially of the hip-joint. He recognized the existence of synovia. He mentions the diaphyses and the epiphyses.

He speaks of the periosteum, the marrow, the inner and outer tables of the skull, and even of the diploë. His knowledge of the muscles was extremely confused. Tendons, ligaments, and even nerves were all, by him, confounded together. He also understood but little of the viscera, mentioning very vaguely mouth, esophagus, stomach, intestines, liver and kidneys. He recognized, however, the peritoneum. He knew somewhat more about the respiratory tract, and still more concerning the glands—for instance, the tonsils, the cervical, axillary, inguinal, and mesenteric glands. Concerning the circulatory system he was, for the most part, deeply in error. In the book "*De Morbo Sacro*" he declares that all the arteries enter the heart. However, he described the heart itself pretty well, mentioning the pericardium, the septum, the auricles and ventricles, the semilunar valves and the chordæ tendiniæ. He knew practically nothing about the organs of special sense.

The *physiology* of Hippocrates was not even so good as his anatomy. First of all, however, let us remark that, in describing his physiology, we shall, of necessity, trench somewhat prematurely on his pathology. Hippocrates, then, assumed that the physical world is composed of just four elements: water, fire, air and earth. This dogma he received, of course, from the Ionic school of philosophy. These four primary elements accounted, he supposed, for the primary, or cardinal, properties of matter: Moisture, warmth, dryness, and coldness. The mixture (crasis) of the four elements in varying proportions produced the different constituents of the human body. There were also, according to his view, four *cardinal fluids*, or *humors*: blood (formed of the moist and the warm); mucus (formed by the moist and the cold); yellow bile (formed of the dry and the warm); and black bile (formed of the dry and the cold). This classification of the four cardinal humors, or fluids, constitutes the basis of the so-called "humoral" pathology. Health, the Father of Medicine believed, was the result of a proper, a harmonious, action and reaction of the various humors on each other and on the various solid tissues; disease, on the other hand, was the result of an inharmonious action of these same cardinal fluids. Faulty admixture of the fluids was called *dyscrasia*, a term in use today but with a different meaning.

Besides the humoral theory, Hippocrates believed also in something which was later to develop into what was called the pneumatic theory. This doctrine taught that a substance essential to life exists in the air (this substance we know today as oxygen,[16] but he called it

[16] The discovery of oxygen was announced by Priestly in 1774, in the first volume of his "Experiments and Observations on Different Branches of Air," etc.

pneuma) and that this pneuma, or spirit, was taken from the air within the trachea and the bronchi by the heart, and, somehow, by that viscus was distributed to the various portions of the body *via* the arteries—which word, we may remark incidentally, meant, simply "air-pipes."

The natural curative force of the body he called *physis*, nature. When physis, or nature, is left to itself, disease runs, normally, a certain course, i. e., through the successive stages of *crudity, coction* and *crisis.* In the first of these stages the fluids of the body—the humors—degenerate, in the second a preparation occurs for their removal, in the third removal takes place. These stages correspond, roughly, with our prodromal period, the period of full development, and the period of decline.

Crises were especially prone to occur on odd, or so-called "critical" days, in which idea a relic is seen of the old Pythagorean philosophy with its deeply rooted belief in the influence of number. In fact there is one whole writing of Hippocrates on the sole subject of "critical days." As a specimen idea from this work we may give this: that decisive days in fever are the 4th, 7th, 11th, 14th, 17th, 21st, 30th, 40th, and 60th. This belief in a mystic relationship of number to the normal functions, and especially the diseases of the human body, runs more or less plainly, like a soiled thread in a pattern, through all the Hippocratic writings. Thus, in a different book from the one just mentioned, he declares that the physician must beware of all odd days, and, among even days, of the 14th, the 28th, and the 42d.

The *semeiology and diagnostics* of Hippocrates were more correct by far than one would really suppose, judging alone from the highly fantastic humoral theory and the doctrine of the influence of numbers. The man was, in fact, so good an observer, that the foolish pathology of his time could only to a very slight degree pervert his judgment. He saw and heard and felt so accurately that he could not draw a great many wrong conclusions. Hippocrates recognized, by the ear, mucous râles and succussion; by the hand he detected changes in temperature, local and general, and pathologic alterations in the pulse; by more than the vision of a Sherlock Holmes he examined all the secretions and excretions of his patients; he even employed accurately the senses of taste and smell—senses which we of today so much neglect. He assisted his natural organs of examination by anal specula, by leaden sounds and garlic-stalks. He took the anam-

In this volume, Priestly called the gas which he had discovered "dephlogisticated air."

nesis carefully [17]—a habit which he had probably acquired from viewing so many clinical histories on the votive tablets, which, as we saw, were hung by departing patients on the walls of Æsculapian temples. Here is one of the anamneses of Hippocrates: "Angina, which had befallen Aristion, in whom it first began in the tongue: speech unintelligible, tongue red and dry. On the first day a rigor and fever, a red superficial swelling upon the neck and breast of both sides, limbs cold, livid, respiration blowing. Drinks regurgitate through the nose, she cannot swallow. Stools and urine retained. On the fourth day all the symptoms are worse. On the fifth she died as the result of the angina."

More important still than his semeiology and diagnostics, at least for modern science, was his *prognostics*. However, as he himself recognized, these two subjects are very closely united. Thus, he declares: "In order to be able to prognosticate correctly who will recover and who will die, in whom the disease will be long, in whom short, one must know all the symptoms, and must weigh their relative value." With regard to the importance of the particular subject in question, he said: "It seems to me best that the physician should acquire practice in the anticipation of the outcome of the disease, for if he is able to recognize in his patients and predict the status præsens, the past and the outcome, as well as that which the patients omit from their accounts of themselves, then he will inspire great faith, and, being thought to know the state of the patient better, the physician will be treated with greater confidence. The treatment will be also better carried out if the ultimate result of the disease is foreseen." So keen was the observation of Hippocrates in the matter of symptoms and so sound the inductions which he made from an enormous quantity of well-observed data, that, in spite of his profound anatomical ignorance, and in spite, also, of his purely fanciful humoral and numeral theories (which he had simply inherited), his work on prognostics possesses high value today. We of the present time, in fact, still call by his name the visage of those about to die from some long-continued or otherwise specially exhausting disease—"the facies Hippocratica," or "Hippocratic countenance." However, Hippocrates did not in the least exaggerate the prognostic value of the pointed nose, the hollow eyes, the sunken cheeks, cold and outstanding ears, etc., and yellow, blue, or purple color of the features. He knew these abnormal indications occurred also in those who were not certainly to die, especially if the appearances in question occurred

[17] Some of the specialists of the present time seem to have "progressed" beyond this.

after hunger, insomnia, and diarrhea. He speaks of carphologia, or picking at the bedclothes, as a bad sign. A favorable symptom in a consumptive patient he said was that wasting did not take place and that hair grew plentifully on the chest. He noted the prognostic value of strabismus in acute affections, also proptosis, and inequality of the pupils. He lays much stress upon the odor which is given off by the patient. Thus he says: "The nose gives, in fever patients, many excellent hints, for the odors are very varied." Vomiting of phlegm and bile well mixed is a good omen, he tells us, but, if the vomitus be colorless, black, or green, the outlook is unfavorable. If the patient vomit all these colors, he is well-nigh sure to die. "In consumptives," he says, "it indicates death when the excretions remain offensive after being shaken with charcoal."

In the field of *treatment*, it would seem that Hippocrates was greater still than he was even in the realms of semeiology and prognostics. Let us consider first his non-operative management of disease, and, later, his surgery.

In the matter of therapeutics he paid particular attention to dietetics—a very remarkable fact when we consider the time in which he lived. Certain sayings of his regarding nutriment are very interesting. Thus he says: "Lean persons should take little food, but this little should be fat; fat persons, on the other hand, should take much food, but it should be lean." Again he says: "Old persons use less nutriment than the young." Further: "In winter abundant nourishment is wholesome; in summer a more frugal diet." Honey-water, sour honey, and ptisane (a decoction of barley) were recommended by him as healthful drinks. The book, "*De Diaeta*," takes up the different articles of food, and discusses them with much detail, and, considering the day, with very great judgment indeed. He frequently prescribed, in connection with a specified diet, baths, exercise, massage, reading aloud and singing.

Treatment by means of drugs, we may be sure "The Father of Medicine" did not neglect—he was not a "therapeutic nihilist." Neither, on the other hand, did he place much faith in "heavy artillery." Drugs he gave to the sick in moderation (some people believe that we had to wait for the nineteenth century to learn to do that), and, for the most part, with a definite aim in view—i. e., he strove to follow the principle of assisting in the elimination of morbific material. This, we can see, was the natural result of belief in the humoral theory of disease, with its corollaries: crudity, coction and crisis. In the stage of crudity, Hippocrates and his followers did very little, if anything. In that stage the Father of Physicians believed that

the indications for interference were, as yet, altogether too uncertain. One could not in that stage determine exactly what kind of trouble was, so to say, "brewing." In the stage of "coction," or "cooking," there were generally definite manifestations, according to the nature of what was being cooked. Means of assisting elimination were gentle purgatives and emetics, and, occasionally, blood-letting. Notice was always to be taken of the paths which the humors seemed to be resorting to naturally; and then the physician's duty was to clear these paths—to give, as it were, nature, or physis, a chance. "What was to be got rid of," he says, "should be derived according to its own tendency, by the appointed ways." Sometimes, however, he thinks, the ways which the humors choose for themselves may be wrong, and then the physician's duty is to lead these errant products into some better means of exit. If, for example, phlegm "tends to pass out by the lungs, it should be drawn away from them in a downward direction."

Hippocrates, however, was far from being so bound up by theories (humoral or other) as not to be able to entertain all facts, whether these appeared to be in favor of his theories or to militate against them. Thus he frankly admits that medicines must sometimes be given empirically: that is, not because their action is understood, but because it is known from observation that they are likely to prove of benefit in the particular class of cases. He even made the observation that disease can sometimes be cured by the administration of a remedy which, in the well, appears actually to produce the symptoms of the disease in question. Thus, he considerably antedated Hahnemann in the discovery of the principle, *similia similibus curantur.* Hippocrates, however, never an extremest in anything, did not push this principle, or any other principle, too far. To the extent to which it was true, he admitted its action—no farther. He knew the advantage of theories, but was not a theorist.

In *surgery,* again, Hippocrates can only excite our wonder and admiration. Certain writers on the history of medicine seem somehow to have misappreciated the great Father of Medicine in this particular realm. Thus, one author, and that a very able and distinguished one, dismisses the subject in twenty or thirty words, remarking that "His surgical practice was not extensive." This undervaluation of Hippocrates's surgery is due, I think, to a saying of him who was father of surgery as well as of medicine, and which ran: "He who desires to practice surgery must go to war." The impression seems to have been derived from this that Hippocrates cared but little about the subject.

Spite of that unfortunate saying of Hippocrates, we may safely allege that Hippocrates' contributions to surgical lore were well-nigh equal to those in the field of internal medicine. He treated fractures admirably, understanding as he did their mode of repair, the duration of the process, the manner in which the various fractures should be reduced and the dressings that should be applied. In the matter of dislocations he was equally learned and skilful. Neuberger says, "The diagnosis and treatment [by Hippocrates] of disease and injury of the osseous system serve as a pattern for all time." Wounds of all sorts he discusses critically, and seems to have handled admirably. He had some dim foreknowledge of asepsis and antisepsis, and bandaged not only neatly, but also with due regard for the ends to be accomplished. He knew of healing by first and second intention. Hernia, tumors, abscesses, ulcers, and fistulæ, were all more or less admirably discussed by him. He performed successfully a number of serious operations, such as trepanning, and paracentesis thoracis and abdominis. He was very fond of the cautery, which, with him, meant, of course, the hot iron. Concerning this manner of treating disease he says: "What drugs fail to cure, the knife cures; what the knife fails to cure, fire cures; but what fire fails to cure, this must be called incurable." He performed several kinds of obstetrical operations, and seems to have been called into cases after the midwives had failed to meet the requirements of the situation. He knew a little about orthopedic surgery, and treated club-foot by manipulation, bandages and specially constructed shoes.

All in all, how much is modern medicine and surgery indebted to Hippocrates? What, in a few brief words, did this man do that the science and art of healing should be called, as it sometimes is, in his honor, "the Hippocratic art"? Here is a general statement of the progress of which he directly and personally seems to have been the cause:

1.—He completed the separation of scientific medicine from temple practice.

2.—He cast away completely all theurgy and magic.

3.—He introduced into medicine the science of observation and inductive reasoning, and

4.—As a corollary to the foregoing, we must say that he avoided the stone wall of the unknowable.

5.—He instituted the wholesome doctrine that the physician, while doing enough, should never do too much. Thus, he taught, "the physician is a servant, not a teacher, of nature."

The weakest point in Hippocratic medicine seems to have been the

failure to distinguish from one another the various individual diseases. Hippocrates, in other words, seems to have understood and treated disease rather than diseases. But, after all, what is it we would have—all things simultaneously? The healing art, in the lifetime of old Hippocrates, actually accomplished far more genuine progress than it had done, before that day, in all the lands of earth in all the aeons of time.

The Father of Medicine, I may now add, practised the art which was undoubtedly very dear to him, in the greater, at least the latter, portion of his life, in the city of Larissa, of Thessaly. He is said to have been, in person, a short man, heavily built, but quick and active in his manner. He was somewhat given to humor and pleasant sarcasm—as doctors are apt to be. According to tradition, he had a very genial countenance, and one full of tenderness and mercy. It certainly must have been a very pleasant face to those who were sick and suffering.

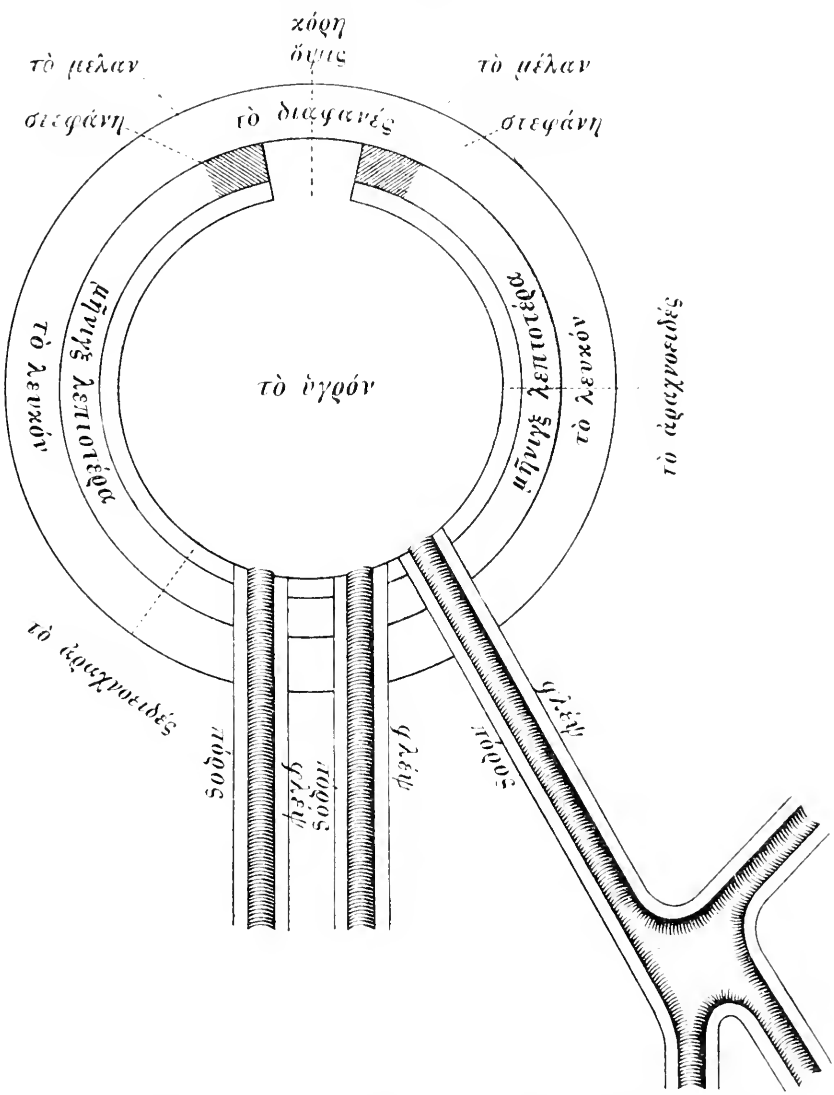
Hippocrates died in Larissa B. C. 370, according to others 377. Till the second century A. D., there was pointed out in Larissa a tomb which was said to be his.

B. HIPPOCRATES AS OPHTHALMOLOGIST.

Having now finished the first division of our present subject, namely, Hippocrates the man and the great all round physician, we come to consider the same great personage in the rôle of ophthalmologist. In this special part of the medical heavens, however, the great star shone with a vastly diminished radiance. He was, to speak literally, not much of an ophthalmologist—saving and excepting always, as a matter of course, in an indirect way—i. e., as the father, or founder, of all modern, or scientific, medicine, ophthalmology included. In that sense, he was the greatest of all ophthalmologists.

Ocular anatomy and physiology.—Hippocrates described the eye as being enclosed by a series of three membranes: an outer, very thick; a middle, thinner; and an innermost which was very delicate indeed. All these three become transparent in the forepart of the eye. The eye is filled by various transparent humors. The surface is often covered by phlegm, but no distinction is made by Hippocrates between the mucous and the lachrymal secretions. The optic nerve had been discovered before the time of Hippocrates, by Alcmaeon, one of the earliest of the Pythagorean philosophers. However, Hippocrates seemed not to have understood the function of this nerve, but rather

to have taken the vitreous humor, and, possibly, the crystalline lens, for the essential, the absolutely necessary, organ of sight.



The Anatomy of the Eye, According to Hippocrates and Aristotle.
(As Drawn by Magnus.)

Ocular pathology.—The ocular pathology of Hippocrates is precisely what a person might expect who had learned somewhat concerning his humoral theory of disease in general. Hippocrates be-

lieved, to put the matter more specifically, that almost all diseases of the eye were produced by what he called catarrh—that is to say, by a descent from the brain to the eye of various injurious slimes, or humors. Hippocrates, in fact, believed that the brain was merely a large gland. Now, there were seven of these corrupt, or injurious, "humors": one passed into the nose, another into the ears, still another into the eyes; one proceeded to the breast, one to the spinal marrow; one to the vertebræ, and one clear down to the hips. The third of these humors produced ophthalmia; the sixth, disturbances of vision. Under the term "ophthalmia" were undoubtedly lumped together, conjunctivitis, blennorrhea, and trachoma. "All the humors," he declares, "which deflect themselves to the eyes, and, at the same time, are characterized by strong and varied acrimonies, ulcerate the lids, and, in some cases, even excoriate the cheeks themselves, and other parts beneath the eyes, upon which they flow. They may also occasion rupture and erosion of the membrane which surrounds the ocular fluids. Pain, heat and extreme burning continue until the humors are concocted and made thicker, and concretions [of gum] are formed around the eyes, the coction taking place from the fluids being mixed, diluted and digested together." Severe catarrhs of the eye soon ending in rupture of the tunics occur especially in cities "exposed to cold winds between the summer settings and the summer risings of the sun," while ophthalmias of a humid character, and not by any means severe, are often to be met with in places exposed to hot winds between the sun's wintry rising and his wintry setting." He also declared that ophthalmias are especially apt to occur in a summer following upon a rainy spring marked by much south wind, when such a spring has been preceded by a dry winter characterized by much north wind. On the other hand, "when the winter has been rich in south wind and in rain and very mild throughout, and the spring has been both dry and wintrish and filled with breezes from the north," then, too, ophthalmias (of the dry variety, however) are especially prone to occur.

In addition to the ophthalmias, there were recognized pterygium, chalazion, ectropium, entropium, trichiasis, ulcers and scars of the cornea, hippus (the modern nystagmus) nyctalopia (the modern photophobia) amblyopia and amaurosis.

Ocular prognosis.—"Especially unfavorable," declares Hippocrates, "are those ophthalmias in which occur pain, swelling and secretion, all in the same cases." Again, "In all acute ophthalmias in which the discharge is greenish or livid and in which there is sleeplessness as well as severe pain in the temples, there is likely to occur ulceration

of the eyeball. In all such cases, perforation may follow. When once the eye is opened," he continues, "and the pupil is projecting from the rupture," it is difficult to bring about a cure. If the sloughing proceed, the eye is lost absolutely. According to the shape and the depth of ulcers which do not perforate, will be the cicatrices which follow upon healing. The various varieties of scars he then describes minutely.

Ocular treatment.—The treatment of ocular diseases in the time of Hippocrates was, just as in the case of the ocular pathology, precisely what one might expect from believers in the humoral pathology in general. In the acuter infections indeed this old-time doctrine ruled like a veritable despot. A restricted diet and hot pediluvia were regarded as extremely important in such diseases. Sternutatories, sharp masticatories and extremely irritant gargles were supposed to be very effective in drawing the "humoral fluxions" away from the neighborhood of the eye. Next in frequency were cupping and venesection. In very severe cases, the burning out of blood-vessels was resorted to as a means of forestalling further "fluxions." This gentle procedure consisted in the application of a red-hot iron to the skin just over the course of a blood-vessel somewhere in the ocular neighborhood, then in cauterizing to such a depth that the vessel was either destroyed, or, at all events, occluded. In still more desperate cases deep parallel incisions were made in various portions of the scalp, most often in the temples and occiput. These incisions were supposed to pass clear through the periosteum, and to afford an exit to the morbid humors which were causing the various ocular difficulties. Local applications were never employed in acute affections of the eye. They might have increased the "fluxions."

In chronic affections local applications were resorted to almost as an absolute rule. Favorite remedies were the milk of women and the gall of goats. Various preparations of copper, iron and lead were employed. Then, too, not infrequently, ebony, myrrh and crocus.

In trachoma, the chief reliance was on "blepharoxysis," sometimes called, but more indefinitely, "ophthalmoxysis." This consisted in rubbing the inner surface of the lid with Milesian wool wound about a spindle-shaped core of hard wood. The process was continued until blood ceased flowing, and, in its place, appeared a thin, water-like liquid. Cauterization of the well-rubbed surface completed this often extremely effective procedure. In fact, it is doubtful if we know of any better means of dealing with trachoma to this day. The blepharoxysis was closely followed up by instillation of collyria which contained, as a rule, the peroxide of copper.

Trichiasis was treated (after epilation) by means of depilatories, the favorite being the juice of wild vine mingled with oil. Surgical treatment was also employed, but the various translators of the *Corpus Hippocraticum* are not at all agreed as to the nature of the operation.

In cases of amblyopia (a term employed in those days to designate such deep affections of the eye as were not accompanied by changes in the color of the pupil) surgery was generally resorted to. The operation was carried out as follows. A deep incision was made through scalp and periosteum. The latter was then shoved aside, and the bone itself either perforated or trepanned.

"Nyktalopia" (which, with Hippocrates, meant little, if anything, more than photophobia) was treated both by medicine and by surgery. The medicine consisted, for specific effect, of liver of ox in honey; for general effect, of purgatives, the object of which, of course, was to "draw away the humors" from the eye. The surgery consisted of deep incisions and cauterizations in the occiput and neck.[18]

II. FROM HIPPOCRATES UNTIL THE MIDDLE AGES.

So ends the first great act in the drama of ophthalmology. Hereafter the multitude of ever-changing actors and groups of actors in

Plato.

this wonderful tragi-comedy, will prosper or will fall (in a scientific sense, of course) precisely as they follow or neglect the guiding principles of old Father Hippocrates.

[18] In the spurious volumes of the *Corpus Hippocraticum* are found a large number of salves, honies, powders, etc., to be applied directly to the eye. Of these, the most in favor contained such substances as: myrrh, wine, honey, white lead, burnt copper, burnt paper, squills, and pomegranate juice.

Soon after Hippocrates came two philosophers, the first of whom cast on medicine in general and ophthalmology in particular a very malignant, the second, however, a very benignant, influence. The first of the two was Plato. Plato lived from B. C. 427 to 347. Unlike Hippocrates, he had a great contempt for facts, for experience, for experimentation. Also unlike the master, he worshipped reason. Plato was, in a word, a leader of the party of speculation. As a single

Aristotle.

example of his medical teaching, we may cite his assertion that the uterus is a "wild beast, totally devoid of human reason, which roams about the body, exciting here and there the most inordinate desire," etc. The perceptions of the senses are mostly illusory, said this philosopher. No wonder that the necessity for accurate and multitudinous observation should have been forgotten by this man and by all who followed his teaching.

Out of that teaching, indeed, arose the medical school called "Dogmatists." This was a sect which placed deduction higher by far than mere experience. It did not wholly reject experience, but it believed

the value of facts to be very slight. Its founders were Thessalus, Draco, and Polybus. Few of the writings of any of the members of this school are extant.

The second of the two philosophers who came soon after Hippocrates, was Aristotle. He lived from 384-321 B. C. Born at Stagira, near Mount Athos, he became physician to the Macedonian King Amyntas, and, afterwards, was appointed tutor to Philip's son, Alexander, who was later to conquer the world. Aristotle was one of the greatest philosophers of all time, the father of rhetoric and logic, almost the creator of natural history, and, undoubtedly, the founder of comparative anatomy and physiology. He was, in fact, the founder of modern non-medical science. He had not the wide immediate following of Plato, but his influence continued to grow until, in the middle ages, his authority had become a positive detriment to science. People would not believe the unquestionable evidence of their own eyes and ears, if it seemed to them to militate against some half-stated view or merest suggestion of a view of Aristotle.

Aristotle's philosophy, which came to be known as the peripatetic philosophy, because of the Master's custom of teaching while he walked about the lyceum, need not detain us here, however interesting.

Aristotle wrote no book on ophthalmology or even on surgery or medicine, and yet so numerous and so important are the observations and inferences which he made concerning the human and the animal eye, that we feel it our duty to remind ourselves of a few [19] of the more important of these matters.

Anatomy.—Aristotle was the first to describe the iris at all well, and even to mention its various colors. He was also the first to observe that all children are born with blue irides.

Physiology.—Aristotle's theory of vision and the nature of light was very much in advance of those of all his predecessors. Thus, Alcmaeon, Anaxagoras, and Democritus had taught that colored images were being continually detached from objects, and that these little masks, or casts, pressing into the eye, were fixed in the pupil, until the soul was able to take note of them. Empedocles, Diogenes, and Plato, on the other hand, had taught that rays of light, running out from the object looked at, were met by other rays which had been emitted from the eye, and that these two varieties of rays, meeting somewhere between the object and the eye, begot, somehow, a third variety of rays, out of which the image was produced, and by which it was, somehow, brought to the soul's attention. Then came Aristotle,

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[19] For the details of Aristotle's ophthalmology, see, in this *Encyclopedia*, **Aristotle**.

with his well-formed, unobscure theory, so greatly in advance of his day as now to seem almost incredibly modern. According to this theory, all the higher sense-perceptions are caused to exist in this way: The object perceived excites a motion, in consequence of which the sense organ is acted upon. What we see of an object is its color; but this we do not see directly, but only through the medium of the light, which the color sets in motion and causes to produce an impression in the organ. Without the light we can see no color, hence no object either. However, the light is not a body, nor is it anything emitted by a body. Nor does it occur of itself, but it is begotten by the motion which is produced by the color of the object looked at. . . . It is here exactly as in the perception of hearing and smelling, for neither the sounding nor the smelling body occasions the sensation by touching the respective sense-organ, but it sets in motion, first, a medium, and, through that, the sense-organ; so, out of the changes in the organs thus produced occur the perceptions of the world of the senses. It is hardly necessary to point out here how like the modern theory of light and of vision this explanation of old Aristotle's is. True as was the theory, however, it met with little favor in antiquity, especially among physicians, and, even in the middle ages, spite of the great authority of Aristotle, it remained without acceptance, save, here and there, by a spirit select, such as the late Arabian, Alhazen, and his successor in these matters, Averröes.

Pathology.—Aristotle knew of errors of refraction and senile failure of accommodation. Of course he did not understand the nature of these troubles, but he speaks of both short-sight and long-sight, contrasting these varieties of visual weakness very thoroughly.

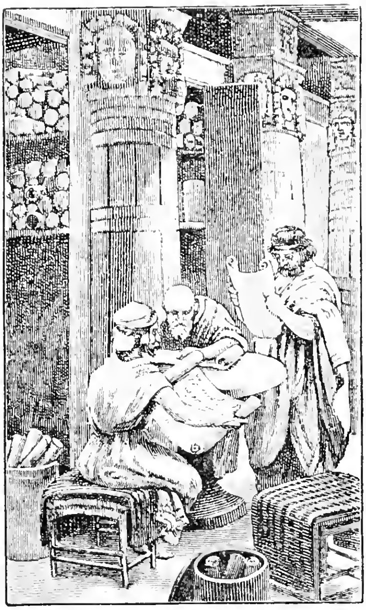
In comparative ophthalmology, as we have said, the Master shone as the bright particular star of all antiquity—in fact until the time of the great Arabian ophthalmologist, As-Sadili, who flourished near the close of the 14th century A. D. So much, moreover, has he left us on this very important subject, that the reader can only be referred for Aristotle's comparative ophthalmology to the article in this *Encyclopedia* entitled **Aristotle.**[20]

The scene again changes to Egypt, but not to the Egypt that we knew before. This is a Hellenized Egypt—Alexandria, and, so to say, the environs of that city. For Egypt has now been conquered (or, rather, been taken without resistance) by Philip's son, the mighty

[20] Which was furnished by the present writer—who desires to accredit all the translated passages in that article to W. Ogle, M. A., M. D., M. R. C. P., in his "*Aristotle on the Parts of Animals.*" This acknowledgment was duly made in a footnote to the former article, but, somehow, was lost either in the typesetting or some of the other processes in the physical manufacture of the volume.

Alexander, an apt pupil of Aristotle, who, to perpetuate his own memory, as well as to strengthen his strategic and political position, founded on the Egyptian coast, at the so-called "Pirate's Bay," a city of enormous size and great magnificence. This occurred B. C. 332.

Nine years later, Alexander died, and, in the apportionment of the civilized world which followed his death, Egypt became the property, or kingdom, of one of his generals, Ptolemy. This man, when he had mounted the Egyptian throne, was known as Ptolemy Soter. He it was who founded the celebrated Library and Museum at Alexandria—



At Work in the Alexandrian Library. (From an Old Woodcut.)

which speedily became the center of learning of the whole world of the day. A vast and beautiful edifice, the building comprised within its walls a portico, an observatory, a library, a public lecture-room of vast dimensions, and a most enormous common-room where all the professors of the institution were accustomed to dine together. The professors formed four faculties—letters, mathematics, astronomy and medicine. The greatest of these by far was that of medicine. All its members were known as "iatrosophists." We would gladly linger a very long time about this ancient university, the memory of which is full of interest and charm, but must hasten onward; for, alas! there is very little known today concerning the ophthalmology of ancient

Alexandria. We know, however, that here our craft, or specialty, was very highly cultivated, though in just what way we can merely guess. This much, however, is known. Herophilus (the founder of human anatomy) invented the name "retina," still in use with its ancient meaning; described the uvea, the vitreous humor and the ciliary processes; and he also wrote a book entitled "*Peri Ophthalmon*": this is the sum and substance of what we know today concerning Alexandrian ophthalmology.

We therefore next consider the medicine and ophthalmology of Rome. And, at the very outset, we may say that all of Roman medicine that was worthy of the name, was not really Roman at all, but

A. Corn. Celsus.

Greek. Even as Alexandrian medicine was simply and solely the medicine of Greece transported into Alexandria, so, too, the medicine of Rome was nothing more or less than the medicine of Greece as it was practised at Rome.

There was nothing at all of medicine at Rome before the invasion of the world capital by the medicine of Greece, excepting the grossest superstition.

The first of the Roman, or, rather, of the Greco-Roman doctors to claim the especial attention of the ophthalmologist, is Aurelius Cornelius Celsus, the author of the famous "*De Medicina.*" A Roman by birth undoubtedly, he wrote in the best of Latin, and yet—his medicine was surely Greek. Some authorities declare that Celsus never practised medicine, but that he was only a dilettante, who, so to say, amused himself with medicine and surgery and wrote a kind of compilation of the subject out of the writings and experiences of

others. Celsus, however, seems to me to have been a practising physician. Hardly a chapter in his work, indeed, but appears to betray that the practice (as distinguished from the mere theoretic knowledge) of medicine was bone of his bone and flesh of his flesh.[21] At all events he was a famous encyclopedist, and the author of the oldest systematic treatise on ophthalmology which has come down to our day.

Celsus was born, presumably at Rome, about 25 B. C., and died in A. D. 50. He therefore straddles, as it were, the beginning of the Christian era. He composed a number of treatises—on agriculture, history, rhetoric, jurisprudence, the military art, and medicine. Of all these compositions that on medicine alone, "*De Medicina*," has come down to our day. The date of this excellent work is about A. D. 29—the same as that of the crucifixion.

The work, *De Medicina*, is composed of eight books. The first treats of hygiene (for the most part dietetics); the second, of general pathology and general therapy; the third of general diseases; the fourth of local diseases; the fifth of materia medica; the sixth of eye, ear, nose, mouth, throat and genito-urinary diseases; the seventh, of surgery: while the eighth, or last, book is devoted to diseases of the bones. The ophthalmic portions of the work consist of chap. VI, of book six, and chap. VII, of book seven. These portions of Celsus's book having been quoted *in extenso* in Vol. III of this *Encyclopedia*, will here be given in briefest abstract merely, and only with a view to showing the great advance which ophthalmology had made since the death of Father Hippocrates.[22]

And, first, the non-instrumental treatment of ocular diseases and injuries—i. e., the portion contained in the author's book VI, chap. six.

First, in this chapter, the writer took up "lippitude," by which he meant ophthalmia—i. e., in a vague way, inflammation of the anterior portion of the eye, not merely a redness and swelling of the borders of the lids—such as the word today would serve to indicate. Celsus considers a number of kinds of lippitude, and is very clear and accurate in the matter of prognosis regarding each kind. Coming to the treatment of each variety of lippitude, he first points out, and truly, that "Hippocrates, the most ancient author we have, has observed in his writings that the eyes are cured by bleeding, by medicines, the bath, fomentations and drinking of wine; but he has not explained the proper times for these, and the reasons for their use;

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[21] A view more positive by far than that which was formerly expressed by me. See beginning of article, **Celsus**, in Vol. III of this *Encyclopedia*.

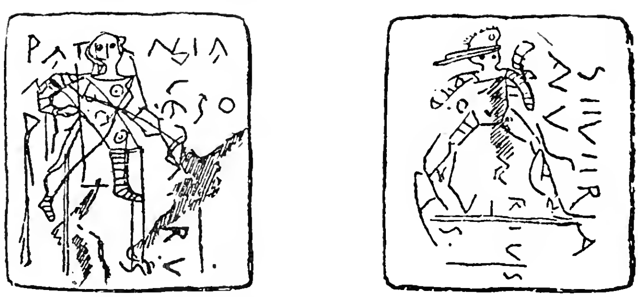
[22] The most of which, of course, was due to the labors of those who had taught and practised in the ancient school, or Museum, at Alexandria—the iatrosophists.

in which the principal part of medicine consists." Celsus then adds to the Hippocratic list, abstinence and clysters, and, throughout the later portion of his chapter, gives far more specific information regarding the use of the Hippocratic remedies than the Father of Medicine gave.

It will be recalled, in this connection, that Hippocrates did not make use of local applications or remedies in the treatment of acute diseases of the eye. Celsus, however, enumerates a considerable number of collyria, which he used in such affections, among them being those of Philon, Dionysius, Cleon, Theodotus and Euelpides.

In fact, he expressly declares that "The more violent any inflammation is, so much the more it requires to be alleviated by medicines, with the addition either of the white of an egg, or breast milk." However, he does not always use his remedies at the very beginning of an acute ocular affection. Thus he says: "On the first day it is not fit to inject anything into the eye, unless the inflammation be very great; for the gum [secretion] is often rather invited than diminished by that means. But, on the second day, even in a severe lippitude, it is proper to relieve by the injection of medicines, when either the patient has been bled, or a clyster has been given; or it appears that neither of these was necessary."

The collyrium of those days, it is just worth while to note in passing, was not (contrary to what the word today implies) a liquid. It

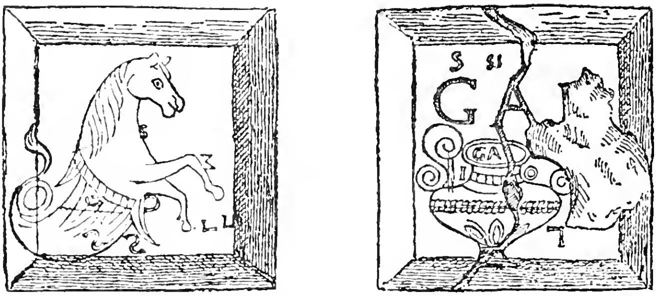


Seal for the So-called "Gladiator" Collyrium. It belonged to an oculist named Paternianus, and was found near Sens (anciently Senones), France.

was, instead, a little cake, or slab, like a tiny bar of soap, on the edges and sides of which were stamped letters, words, or rude designs, to indicate the chief ingredients, the name of the inventor or prescriber, and the particular disease or diseases for which the collyrium was supposed to be useful. The seals, or stamps, employed for the printing of these words and letters have been recovered in very large

numbers, especially in western Europe. In order that collyria might have the right consistency, gums were almost always included among their ingredients. Before using, the cake, or a portion thereof, was dissolved in water or oil. It is possible that, now and then, the cake, or bar, held cornerwise, was employed as a "pencil."

But collyria were not the only remedies which Celsus employed locally. Mother's milk and cow's milk, white of egg and yolk of egg, either alone or mixed with mulse, were soaked into pledgets of "soft wool combed," which then were laid upon the eyes. Boiled barley



An Unusually Interesting Collyrium-Seal. The stone is dark green in color, and highly polished. On one side is the figure of a sea-horse; on the other, an amphora.

meal mixed with boiled quince was favored as a poultice. A penicillum[23] squeezed out of water, or, if the disease were more severe, out of water and vinegar, was often laid upon the eyes—with benefit, of course.

Regarding Celsus's constitutional, or general, treatment of diseases of the eye, we have already spoken, when adverting to his remarks upon Hippocrates.

For chronic inflammation of the eyes, Celsus, like the founder of our art, makes use of local (as well as general) applications freely. For these he employs especially the collyrium of Andreas, as well as, often, those of Hierax and Hermon. Specially named collyria are the Phynon, the Sphærion, the Pyxinum, and the Basilicon, all of Euelpides, as well as the Asclepias, the Cæsarian, and the Rhinion, whose inventors are not mentioned.[24]

The collyrium was wholly unknown to Hippocrates.

Among the chronic inflammations of the eye, or "lippitudes," our author includes the condition called today *trachoma*, without, how-

[23] Which meant, originally, a small painter's brush.

[24] The composition of each of these collyria is given in full in the article, **Celsus**, in Vol. III of this *Encyclopedia*.

ever, applying a special name thereto. His treatment for this affection (which is really the opthalmoxysis, or blepharoxysis, of old Hippocrates) is very interesting: "And others are useful too; which are calculated to lessen the roughness of which I am going to speak. This commonly follows an inflammation of the eyes; sometimes it is more violent, at others more slight. Sometimes, too, a roughness occasions a lippitude, and that again increases the roughness, and in some it is short, in others it continues a long time, and so as to be hardly ever cured. In this kind of disorder some scrape the thickened hard eye-lids both with a fig-leaf and a specillum asperatum, and sometimes with a knife; and turning them up, they rub them every day with medicines. Which ought not to be practised, unless in a considerable and inveterate roughness, nor that often. For the same end is better obtained by a suitable regimen and proper medicines. Therefore we shall use exercises and the bath more frequently; and foment the eyelids with plenty of warm water. The food must be acrid and extenuating." He also gives, a little later, a collyrium, that of Hierax, which, he says "is powerful against a roughness."

Proptosis.—For this affection, by which our author understands a prolapse, or at least a hyperprominence, of the eyeball,[25] he chiefly relies on venesection (when the strength of the patient permits) on clysters and on long fasting. He also advises the milder of Cleon's collyria, as well as (best of all) the collyrium of Nileus.

Carbuncles.—For these he advises chiefly clysters and milk diet. He also employs the collyrium of Nileus, "but if the carbuncle be on the external part of the eyelid, linseed boiled in mulse is the most proper for a cataplasm; or if that is not to be had, wheat meal boiled in the same manner."

Pustules of the eyes.—For these he relies on bleeding and rest, as well as clysters and restricted diet. If these do not suffice, he resorts to the collyria of Nileus and Cleon. If ulcers occur, he employs "a particular application," called "dialibanou." This consisted of copper calcined and washed, as well as poppy tears toasted, and a number of other ingredients.

Wasting of the eyes.—Breast milk, the milder kinds of collyria, and the avoidance of worry and acrid foods.

Phthiriasis.—For lice on the eyelids (which Celsus thought resulted from "a bad habit of the body") are recommended gargles, fomentations of the head, and a wash made of aphronitre, sandarach, and

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25 In the Greco-Roman middle ages the expression, "proptosis," meant a prolapse of the iris alone.

stavesacre, powdered together and mixed with equal quantities of old oil and vinegar "till the whole come to the consistency of honey."

Cataract.—Especially interesting, however, is the medical treatment which Celsus recommends for what the Romans called "suffusio" and the Greeks "hypochyma," but which we today (as followers in this regard of Constantinus Africanus—A. D. 1018-1085) denominate "cataract." This disease, at the beginning, he says, may be "discussed by certain methods adapted to the case. It is expedient to bleed in the forehead or nose; to cauterize the veins in the temples; by the use of gargarisms to evacuate phlegm; to use fumigations; to anoint the eyes with acrid medicines. . . . If the disorder is inveterate," he adds, "it requires an operation." The surgical procedure is then discussed in chap. 7, of book VII, along with the other instrumental treatment of the eye.

Palsy of the eyes.—For this affection, by which he understands, in greater part, what is called today "nystagmus," Celsus declares that nothing at all can be done.

Mydriasis.—Of this affection he says, "The pupil is dilated, the sight grows dull and almost dim." Declaring the disease to be most difficult to cure, he recommends especially the anointing of the eyes with honey, as well as vigorous purgation.

The chapter on the medicinal and hygienic treatment of the eyes concludes with a section. each, on "weakness of the eyes" and "on external hurts of the eyes," neither of which need here detain us.

Passing now from book VI, chap. 6, to book VII, chap. 7, we proceed to examine hastily the ocular surgery of Celsus.

Crithe.—For a crithe, or stye, Celsus applies hot bread or hot wax, "for by this method it is often discussed [caused to disappear] sometimes maturated. "If pus appear, it ought to be divided by a knife, and the contained humor squeezed out." Then again, warmth.

Chalazia.—Celsus's treatment of chalazia, like that for crithes, is still in use. Thus, he says, "these ought to be cut on the external side, if they be immediately under the skin; on the internal, if they lie below the cartilage; after that, they must be separated by the handle of the knife from the sound parts."

Pterygium.—Of this affection, called by the Romans "unguis," Celsus says, wrongly of course: " . . . it is no difficult matter to discuss this, when recent, by the medicines which lessen cicatrices in the eyes." However, he adds: "If it be of long standing and has acquired some thickness, it ought to be cut out." The procedure of removing the growth is then described as follows: "After an abstinence of one day, the patient must be placed in a seat, either with

his face opposite to the physician, or with his back to him, in such a manner, that he may recline his head upon the physician's breast. Some, if the disease be in the left eye, choose to have him sit with his face to the physician; if in the right, in the reclined posture. One eyelid ought to be opened by an assistant, and the other by the physician. If the physician face him, he must take hold of the lower one; if he be reclined, the upper one. Then the physician is to fix under the extremity of the unguis, a small sharp hook, with its point turned a little inward; and to let go the eyelid, which is then to be held by an assistant, and taking hold of the hook, he is to lift up the unguis, and pass a needle through, drawing a thread after it; then to lay aside the needle, and take hold of the ends of the thread, and by them raising up the unguis, if it adheres anywhere to the eye, to separate it by the handle of the knife, till he come to the angle; then alternately sometimes to slacken, sometimes to draw, it, that so both its origin and the extremity of the angle may be found. For there is a double danger attends it; either lest some part of the unguis be left, which being ulcerated is hardly ever cured, or lest the caruncle be cut away from the angle; for if the unguis be drawn away with too much force, that also follows and comes away. If it is torn off, an orifice is opened, through which afterwards a humor always descends, which the Greeks call rhyas. The true termination then of the angle must be found out. When that plainly appears, the knife is to be used, the unguis not being too straight drawn; and then this small membrane is to be cut out in such a manner, that no part of the angle is wounded. Afterwards lint, covered with honey, must be laid on, and over that a linen cloth, and either sponge, or succid wool. The following days, the eye must be opened daily, lest the eyelids be agglutinated together by a cicatrix (for that is also a third danger) and lint be put on in the same way; lastly, it must be anointed with a collyrium, that cicatrizes ulcers.

Encanthis.—By the term encanthis was understood by Celsus precisely the same affection, or, rather, group of affections, as by opthalmologists today. Taking the tumor on a hook, he cut it round, being "cautious not to cut away anything from the angle itself." A dressing of cadmia or copperas is then employed in the conjunctival sac.

Ankyloblepharon.—The meaning of this term too has not changed. Celsus remarks (and rightly) of the affection in question, "When the eyelids only cohere, they are separated without difficulty: but sometimes to no purpose; for they are agglutinated again." His procedure is as follows: "The broad end of the probe is introduced between them, and the eyelids separated by that; then small penicilla are to

be put between them, till the ulceration of the part is cured. But when the eyelid adheres to the white of the eye itself, Heraclides the Tarentine advises to cut under it gently with a knife with great caution, lest anything be cut away either from the eye or the eyelid; and if that cannot be entirely avoided, rather to take something from the eyelid. After these, let the eye be anointed with such medicines as cure an asperity [trachoma]; and let the eyelid be inverted every day, not only that the medicine may be applied to the ulcer, but also to prevent its adhesion; the patient himself must also be charged to raise it often with two fingers." He then proceeds: "I do not remember an instance cured by this method.[26] Meges, too, tells us he tried many ways, and never was successful, for the eyelid always adhered again to the eye."

Lachrymal fistula.—This was called by Celsus "ægilops." After describing the affection better than had ever been done before, he remarks: "It is dangerous to attempt the cure of those [cases] that are cancerous; for it even hastens death. And it is needless to meddle with such as reach to the nostrils; for neither do they heal. But the cure of these in the angle may be attempted; though it should be known however that it is difficult; and the nearer to the angle the opening is, so much the more difficult, because there is very little room for the management of the hand." Having observed that the disorder is easier to cure when recent, Celsus proceeds to describe the operation: "The top of the opening must be taken hold of with a small hook; and then all the cavity, as I directed in fistulas, must be cut out to the bone; and the eye and other contiguous parts being well covered, the bone must be strongly cauterized with a hot iron. But if it be already affected with a caries, that a thicker scale may cast off, some apply caustic medicines; as copperas, or chalcitis, or rasile verdigris; which method is both slower, and not so effectual. When the bone is cauterized, the remaining part of the cure is the same as in other burns."

In view of the fact that neither the lachrymal apparatus nor any of its diseases were mentioned in the pre-Alexandrian period, even by Father Hippocrates[27] or Aristotle, the advance in respect to these

[26] This is one of the expressions which has served to convince me thoroughly that Celsus, when he wrote his book, had been engaged in the active practise of medicine for a considerable number of years. We must, I think, on the strength of this one passage alone (and there are many others of similar bearing) acknowledge the point in question—or else be obliged to take the position that the excellent author of "*De Medicina*" was what today is called a "bluffer." That position, however, is hardly tenable, for the very simple reason that "bluffers" do not, as a rule, acknowledge that they "do not remember an instance of one person cured"—being more inclined to miracles.

[27] The Hippocratists believed that the tears proceeded from the brain—which was by them regarded simply as a large gland. Plato believed that the tears

affections is very pronounced. However, even Celsus did not know of the existence of either the lachrymal drainage or the lachrymal secretory apparatus. The caruncle indeed was known to him, though he called it not "caruncula lacrymalis," but, simply, "caruncle."[28] Galen (who lived a century and more after Celsus) knew of the existence of the lachrymal glands (but not their function) and also of the tiny passages which led down into the nose and carried moisture either (as he thought) to or from the eye, according to the requirements of this organ. Of Galen's views, however, we shall speak in detail hereafter.

Trichiasis and distichiasis.—For these affections the methods of cure of Celsus were as follows: "If preternatural hairs have grown, an iron needle, thin and broad, like a spatha, must be put into the fire, and when it is red-hot, the eyelid being lifted up in such a manner, that the offending lashes are in the view of the operator, it must be passed from the angle close to the roots of the hair, till it move over the third part of the eye-lid; then it must be applied a second and third time, as far as the other angle. The consequence of which is, that all the roots of the hairs being burnt, die away. Then a medicine to prevent an inflammation must be applied; and when the eschars have cast off, it must be brought to cicatrize. This kind heals very easily. Some allege that it is proper to pierce the external part of the eye-lid near the eye-lashes with a needle, which must be passed through with a woman's hair doubled for a thread; and when the needle has gone through, that the offending hair must be taken up into the loop of the woman's hair, and by that drawn upward to the superior part of the eyelid, there to be glued down to the flesh, and a medicine applied to close up the orifice thus made; for that this will cause the eye-lash to point afterwards externally. This in the first place cannot be practised, but upon a pretty long hair; whereas they generally grow short there. And then, if there be several hairs, the patient must suffer a long torture, and the needle passing so often through, will raise a great inflammation. Lastly, when any humor is settled there, the eye being irritated both before by the hairs, and afterwards by the perforations of the eyelids, it is hardly possible to prevent the glutinous matter, which fastens the hair, from being dis-

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arose from a mixing of the "visual fire" with the natural moisture in the eye—the "visual fire" being the essential principle whereby the act of vision was performed. The special necessity for an exit for the tears from the conjunctival sac did not seem to have occurred to any of the earlier workers—even, as abovementioned, to Celsus himself.

[28] To the Greeks of the time of Celsus (which means the most of the physicians who were practising in Rome) the caruncle was known as *sarkodes soma*—i. e., fleshy body.

solved; and thus of course the hair returns to the place from whence it was drawn away.

"The method of cure for a relaxed eyelid, [this, he says, is the cause of some trichiasis] which is universally practised, never fails of success. For the eye being closed, one must take hold of the middle part of the skin of the eyelid, whether it be the upper or the lower, with his fingers, and raise it, then consider how much must be taken away, to reduce it to its natural condition. For there are two dangers attending this case; lest if too much be cut off, the eye cannot be covered; if too little, the end be not obtained, and the patient have suffered to no purpose. The part which it shall be thought needful to cut, must be marked by two lines with ink in such a manner, that between the range of hairs and the line nearest to it, some space may be left for the needle to lay hold of. These things being determined, the knife is to be used; and if it be the upper eyelid, the incision next the eyelashes must be made first; if the inferior one, last; and it must begin in the left eye, at the angle next the temple; in the right, at the angle next the nose; and what lies between the two lines must be cut out.[29] Then the lips of the wound are to be joined together by a single stitch, and the eye must be covered; and if the eyelid does not descend far enough, it must be relaxed; if too much, it must be the straighter drawn, or a small habenula again cut off from that lip of the wound, which is farthest from the eyelashes. When it is cut off, other stitches must be added, not above three. Moreover a scarification must be made in the upper eyelid, under the roots of the eyelashes, so that, being raised from the inferior part, they may point upwards; and this alone will be sufficient for the cure, if they are but little turned in. The lower eyelid does not need this process. When these are done, a sponge squeezed out of cold water must be bound on; the day following, an agglutinating plaster should be applied. On the fourth, the stitches must be taken away, and the wound anointed with a collyrium, to prevent an inflammation."

Now, in the genuine writings of Hippocrates there is nothing at all on the treatment of trichiasis. In one of the spurious Hippocratic works, however, produced, perhaps, before the founding of Alexandria, occurs the following passage: "Trichiasis. Through an eyed needle, draw a thread, and at the border of the [lower] lid (with its arch directed upward) thrust the needle through in a downward direction, draw the thread through, and place a second suture below the first. Pull the threads tight, and knot them with one another. They are

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[29] No such detailed instructions are found in any other writings on ocular surgery prior to the time of Celsus.

then to be kept together until they fall from the eye of themselves. When this is not sufficient, one must try again." It is hardly necessary to indicate the great advance which had been accomplished by the time of Celsus.

Lagophthalmus.—"Sometimes, from this operation" [the second procedure above described for trichiasis] Celsus proceeds to admit, "when too much of the skin is cut away, it happens that the eye cannot be covered. And this sometimes proceeds from another cause. The Greeks call the disorder lagophthalmos (or hare's eye). When too much of the eyelid is wanting, there is no remedy for it; if but a small part, it may be cured. An arched incision must be made in the skin, a little below the eyebrow, with its horns pointing downward. The wound ought to go as deep as the cartilage, but without injuring it; for if that be cut, the eyelid falls down, and cannot afterwards be raised. Let the skin then be only divided, so as to allow it to descend a little in the lower part of the eye; which will be the consequence of the wound's gaping above. Let lint be put into it to prevent the union of the divided skin, and to generate a little flesh in the middle; and when this has filled up the part, the eye is afterwards properly covered by the eyelid."

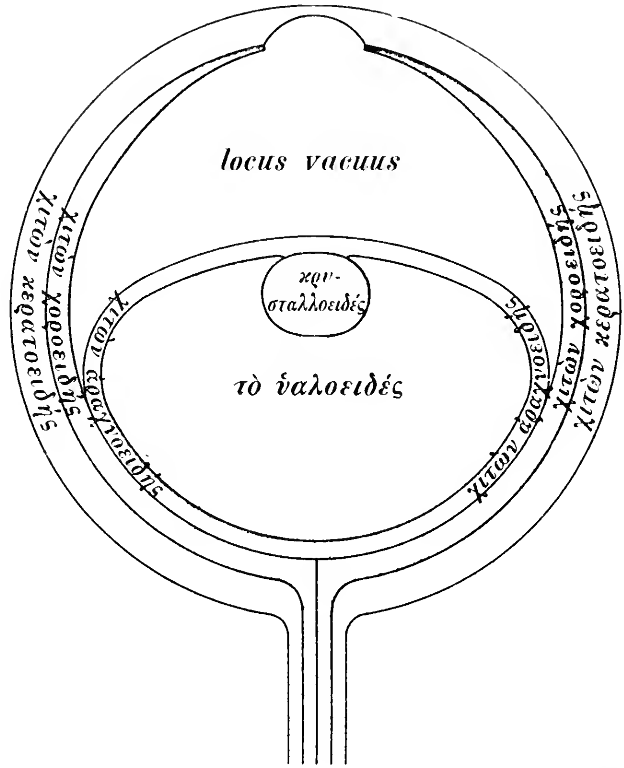
All this Celsean matter on the treatment of lagophthalmus is absolutely new. There is nothing at all on this subject in Hippocrates or Aristotle or in any of the writers whose works have come down to our day.

Ectropion.—Having discussed the etiology of this trouble, Celsus thus remarks upon its treatment: "If it happens from a faulty cure, the treatment is the same as in the foregoing case; only the horns of the wound are turned towards the cheeks, and not to the eye. If it proceed from old age, the whole of it must be cauterized externally with a thin plate of iron; then anointed with honey; and from the fourth day fomented with hot water, and anointed with medicines to bring on a cicatrix."

In none of the earlier authors is the slightest mention made of a surgical treatment for ectropion. The condition itself, as a matter of course, had been described by a number, e. g., by Hippocrates, and treatment of a medical character for the affection in question is mentioned in the old papyrus Ebers. Nothing adequate, however, appears in the literature until this passage of Celsus.

Staphyloma.—"In the eye itself," says Celsus, "the external coat is sometimes raised, either from the rupture or relaxation of some of the internal membranes; and it resembles a raisin stone in its form, whence the Greeks call it a staphyloma. There are two methods of

cure for it. One is to pass through the middle, at the root of it, a needle with a double thread; then to tie tight the ends of one of the threads above, and of the other below; which, by cutting it gradually, may bring it off. The other is, to cut out from its surface about the bigness of a lentil; then to rub in spodium or cadmia. When either of these is done, the white of an egg must be spread upon wool and



The Anatomy of the Eye, According to Celsus. (As Drawn by Magnus.)

applied; and afterwards the eye must be fomented with the steam of hot water, and anointed with mild medicines."

The ocular anatomy.—Passing by Celsus's remarks on clavi, or "callous tubercles in the white of the eye," we come to his section on the surgical treatment of cataract—perhaps the most valuable and interesting of all the sections in the Celsean ophthalmology. Before, however, our auther proceeds to discuss the very important affection known as cataract, he describes by way of preface, the anatomy of the eye. Here is the passage *in extenso* "Description of the Eye.—I have already elsewhere mentioned a cataract, because when recent,

it is often removed by medicines. But when it is of long standing, it requires a manual operation, and one which may be reckoned amongst the nicest. Before I treat of this, I shall give a short account of the nature of the eye; the knowledge of which, as it is of importance in several other parts, so it is peculiarly necessary here. The eye, then, has two external coats; the exterior of which by the Greeks is called ceratoides; and this, where it is white, is pretty thick, but before the pupil is thinner. The interior coat is joined to this, in the middle where the pupil is, and is concave, with a small aperture; round the pupil it is thin, but at a distance from it, something thicker; and by the Greeks is called chorioides. As these two coats surround the internal part of the eye, they again join behind it, and becoming finer, and uniting together, pass through the opening, which is between the bones, to the membrane of the brain, and are fixed to it. Under these, in the part where the pupil is, there is void space; then again below is an exceeding fine coat, which Herophilus called arachnoides, the middle part of which subsides, and in that cavity is contained somewhat, which, from its resemblance to glass, the Greeks call hyaloides. This is neither liquid nor dry; but seems to be a concreted humor; from the color of which, that of the pupil is either black or gray, though the external coat be white. This is enclosed by a small membrane, which proceeds from the internal part of the eye. Under these is a drop of humor, resembling the white of an egg, from which proceeds the faculty of vision. By the Greeks it is called chrystalloides."

A reference to the accompanying cut of the eye as understood by Celsus, will render somewhat plainer the ambiguities and other obscurities in Celsus's description. A comparison of this cut with that exhibited herein a little earlier, showing the anatomy of the eye as understood by Hippocrates, will show that a merely slight advance in ocular anatomy had been made. The most important discovery would seem to be the chrystalloides, or lens crystallina, which is nearly offset by the very remarkable error committed in supposing a "locus vacuus" to exist between this structure and the iris.

In this "locus vacuus" it was, however, that Celsus supposed a cataract lay. He, in fact, fancied that a cataract (which, in his day, was known in Latin as "suffusio" and in Greek as "hypochyma") was simply an inspissated humor which had flowed down into the "locus vacuus," there to constitute an obstruction to the sight. The ancient operation for suffusio (or cataract) was, when successful (and sometimes when not) what today is known as a "depression." But the ancient operator had no thought at all that what he was doing

was dislocating the crystalline lens. In fact he believed the lens to be the essential organ of vision, as we today think, or rather know, that the retina is. A dislocation of the lens would, to him, have meant absolutely nothing more or less than absolute blindness. What he thought he was doing when performing a cataract operation, was, tearing away from a (wholly imaginary) space between the pupil and the lens a mass of "inspissated humor," which had "flowed down" (hence the later expression, "cataracta") into that space, and, later, gone through some sort of process of thickening and drying. What he was really doing, however, was, now and then, to fumble ineffectually at a hypopion, again to tear, more or less ineffectually, at a pupillary membrane, or at a vitreous opacity, or, once more, to recline an actually opaque lens—in the last-named instance, of course, very often with good results.

For the sake of a connected narrative, we may here anticipate a little and render the following exceedingly condensed account of the future development of the "suffusio" or cataract operation: In the middle ages, an Arab, Ammar (in the earlier portion of the 11th century) invented the suction operation, and, after that, there were practised the two procedures—reclination and suction. But the pathological conception of a "suffusion," or "cataract," remained the same.

A great French ophthalmologist, St. Yves, was the first in history (1707) to extract the lens; but it was only a lens which had been already dislocated into the anterior chamber. For St. Yves's greater compatriot, Jacques Daviel, remained the incomparable honor of being the first to extract a cataract from its normal position behind the pupil. The first publication of this procedure was in 1748.

One ought to add, for the sake of perfect clearness, that ancient authors, and sometimes those of the middle ages, did sometimes speak of "extracting" a cataract. But what they meant, beyond all question, was not the extraction of an opaque lens from the eye as a whole, but only of an inspissated membrane from the space which they believed to exist between the lens and the pupil, down into a lower space.

Celsus's cataract operation.—We are now, I believe, in a better position to understand precisely what it was that our author meant by a cataract (or "suffusio") as well as exactly what it was that he was accustomed to doing in order to remove such an impediment to the sight. Here is the passage in an almost literal translation: "Now a humor concretes under the two coats, where I mentioned the void space to be, either from a disease, or a blow; and being gradually in-

durated, it obstructs the interior faculty of vision. There are several species of this malady, some of which are curable, and others not. For if the cataract be small, immovable, of the color of sea-water, or burnished iron, and leaves some sense of light on its sides, there remains hope. If it is large, if the black part of the eye, losing its natural appearance, is changed into some other, if the cataract be of the color of wax or gold; if it slides and moves to and fro, it is scarcely ever cured. And for the most part, the more severe the disease, or the greater the pains of the head, or the more violent the blow has been, which gave rise to it, so much the worse it is. Neither is old age a proper time of life for a cure, which, without an additional disease, causes a dimness of sight; nor even childhood; but the middle age between these. Neither is a very small eye, nor one that is hollow, fit for this operation. And there is also a certain maturity of the cataract itself; wherefore we must wait till it seems to be no longer fluid, but to have concreted with a certain degree of hardness.

"Before the operation, the patient must use a spare diet, drink water for three days, the day immediately preceding take nothing at all. After this preparation, he must be set in a light place, in a seat facing the light, and the physician must sit opposite to the patient, on a seat a little higher, an assistant behind taking hold of the patient's head, and keeping it immovable; for the sight may be lost forever by a slight motion. Moreover, the eye itself, that is to be cured, must be rendered more fixed by laying wool upon the other, and tying it on. The operation must be performed on the left eye by the right hand, and on the right eye by the left hand. Then the needle sharp-pointed, but by no means too slender, is to be applied, and must be thrust in, but in a straight direction, through the two coats, in the middle part between the black of the eye and the external angle opposite to the middle of the cataract, care being taken to wound no vein. And it must not be introduced with timidity either, because it comes into a void space. A person of very moderate skill cannot but know when it arrives there; for there is no resistance to the needle; when we reach it, the needle must be turned upon the cataract, and gently moved up and down there, and by degrees work the cataract downward below the pupil; when it has passed the pupil, it must be pressed down with considerable force, that it may settle in the interior part. If it remain there, the operation is completed. If it rises again, it must be more cut with the same needle, and divided into several pieces: which, when separate, are both more easily lodged, and give less obstruction. After this the needle must be brought out in a straight direction, and the white of an egg spread upon wool must be applied,

and over that something to prevent an inflammation, and then the eye be bound up.

"Afterwards there is a necessity for rest, abstinence, mild unctuous medicines, and food (which it is soon enough to give on the day following) at first liquid, that the jaws may not be too much employed, then, when the inflammation is gone, such as was directed in wounds. To which we must add this rule, that the patient's drink be water for a pretty long time."

A flux of gum.—The last of the maladies which Celsus treats by instrumental interference is what he calls a "flux of gum"—i. e., the continual discharge of a thin "humor" with resulting "asperities, inflammations and lippitudes." This condition he treats in a number of the same barbarous ways which had been employed by Hippocrates. These methods consisted: (1) In cutting the skin of the head in (usually nine) lines, lifting then the edges of the wounds by means of blunt hooks, and inserting lint pledgets, in order that "flesh . . . might spreut up in the middle" and "bind those veins from which the humor passes to the eyes." (2) In cauterizing the veins of the temples, setting sometimes a ligature about the neck, to make the vessels stand out plainly. (3) (The method of the Africans!) In burning "the crown of the head to the bone, so as to make it cast off a scale." The details of all these barbarous methods we need not here go into. Suffice it that, in these few matters, our author was not so much as a single step advanced beyond the Hippocratic period. In fact, in some respects, he was rather behind it.

In spite, however, of one or two shortcomings, a decided advance is easily to be noted in the Celsian ophthalmology as compared with that of Hippocrates. How much of this was due to the old iatrosophists, the teachers in the medical school at Alexandria? How much, on the other hand, to Celsus himself, or at least to his contemporaries? Nobody knows, or ever will know, in all human probability, until the end of time. Suffice it, at all events, that Celsus, physician or no physician, inventor or mere compiler, sincere and earnest worker or fraudulent pretender, has left us the greatest work on ophthalmology that has come down from his day. The book is also, in a sense, the greatest ophthalmic writing of antiquity until the time of Galen.

Of Galen, however, hereafter. Meantime, we needs must speak of a couple of contrasting characters who came between these two ophthalmologic giants—Pliny the man of the people and of superstition, and Rufus, who composed the oldest scientific anatomy which is still in existence.

Almost contemporary with Celsus, but probably somewhat older,

was the elder Pliny, Gaius Plinius Secundus. He was a decidedly different kind of man from Celsus, Celsus being a follower of Hippocrates, and Pliny of—as one might say—Marcus Porcius Cato *et id genus omne.* Pliny was born in Upper Italy A. D. 23, and died in 79 in that particular eruption of Vesuvius by which Pompeii and Herculaneum were destroyed. (Celsus had passed away in A. D. 50.) Though an imperial governor and busy Roman military officer, Pliny somehow found the time to become a universal scholar and to write a number of interesting, as well as very useful, books. These works, however, have met with a similar fate to those of Celsus—only one of them has come down to our day—the famous *Historia Naturalis.* In addition to this, there were works on war, biography, grammar, history and rhetoric.

The monumental extant work—*the "Natural History"*—is, in fact, the greatest treasury of ancient Greco-Roman knowledge that we now possess. Compiled from about 2,000 writings of 474 authors, it deals, in the following order, with astronomy, physics, geography, ethnography, anthropology, zoölogy, botany, mineralogy, pharmacology, medicine, painting, sculpture, the engraving of gems, and comparative geography. The enormous work was planned, executed and revised in the space of two years—77-78 A. D. As a result, in part at least, of the haste with which the book was put together, it contains (in spite of its very great value) a large number of mistakes. Then, too, Pliny was, as it seems, by nature a very careless writer, and, in addition, a man devoid of critical acumen and deeply tinctured with superstition.

It is chiefly, of course, the medical portions of the great book of Pliny that are of interest to physicians. Pliny, however, we may say at the outset, was not favorable to doctors, as the following extracts from his writings abundantly prove: "And there is no doubt that they all busy themselves with our lives, in order by the discovery of some new thing or another to win reputation for themselves. Hence flow those pitiable disputes over the sick; for no one has the same views as another; hence also that inscription upon the tombstone of the unfortunate victim: 'He died by reason of the confusion of the doctors.' This spurious art is changed so often and so lamentably, and we are driven to and fro by the breath of the spirits of Greece." Again: "There is, alas, no law against incompetency, no striking example is made. They learn by our bodily jeopardy, and make experiments until the death of the patients. And the doctor is the only person not punished for murder."

In spite, however, of Pliny's all too plainly expressed disgust and contempt for medicine and doctors, his observations on matters con-

nected with the eye are of interest to the modern ophthalmologist—some of them for one reason and some for another. We cannot in this place give all the passages from Pliny which deal with the eye or its affections,[30] but present instead a few choice specimens which will very clearly show that Pliny, however important in other fields than ophthalmology, possesses for our specialty no scientific, or historical, though a very decided antiquarian, interest. Ophthalmologically, and even medically, speaking, he is not in the scientific line of descent, but the superstitious.

Here is the first of his passages which have an ophthalmic bearing:

"Book II. Chap. 41.—Of the Regular Influence of the Different Seasons.

". . . certain accurate observers have found out, that the entrails of the field-mouse correspond in number to the moon's age, and that the very small animal, the ant, feels the power of this luminary, for she always refrains from her labors at the changing of the moon. And so much the more disgraceful is our ignorance, as everyone acknowledges that the diseases in the eyes of certain beasts of burden increase and diminish according to the age of the moon . . ."

Here is a part of the next ophthalmic passage that occurs in the book in question:

"Book VII. Chap. 2.—The Wonderful Forms of Different Nations.

". . .

"In the vicinity also of those who dwell in the northern regions, and not far from the spot from which the north wind arises, and the place which is called its cave, and is known by the name of Geskleithron, the Arimaspi are said to exist, whom I have previously mentioned, a nation remarkable for having but one eye, and that placed in the middle of the forehead. This race is said to carry on a perpetual warfare with the Griffins, a kind of monster, with wings, as they are commonly represented, for the gold which they dig out of the mines, and which these wild beasts retain and keep watch over with a singular degree of cupidity, while the Arimaspi are equally desirous to get possession of it. . . .

". . . The same author relates, that there is, in Albania, a certain race of men, whose eyes are of a sea-green color, and who have white hair from their earliest childhood, and that these people see better in the night than in the day . . .

". . . Isigonus adds, that there are among the Triballi and the Illyrii, some persons of this description, who also have the power of

[30] They are given in full in the present writer's article in this *Encyclopedia*, entitled "**Pliny.**"

fascination with the eyes, and can even kill those on whom they fix their gaze for any length of time, more especially if their look denotes anger; the age of puberty is said to be particularly obnoxious to the malign influence of such persons.

"A still more remarkable circumstance is the fact that these persons have two pupils in each eye. Apollonides says, that there are certain females of this description in Scythia, who are known as Bythiæ, and Phylarchus states that a tribe of the Thibii in Pontus, and many other persons as well, have a double pupil in one eye, and in the other the figure of a horse."

And here is a sample of Pliny's comparative ophthalmology—far inferior to that of his Greek predecessor, Aristotle.

"Chap. 52.—The Eyes—Animals Which Have No Eyes, or Have Only One Eye.

"Below the forehead are the eyes, which form the most precious portion of the human body, and which, by the enjoyment of the blessings of sight, distinguish life from death. Eyes, however, have not been granted to all animals; oysters have none, but, with reference to some of the shell-fish, the question is still doubtful; for if we move the fingers before a scallop half open, it will immediately close its shell, apparently from seeing them, while the solen will start away from an iron instrument when placed near it. Among quadrupeds the mole has no sight, though it has something that bears a resemblance to eyes, if we remove the membrane that is extended in front of them. Among birds also, it is said that a species of heron, which is known as the 'leucus,' is wanting of one eye: a bird of most excellent augury, when it flies toward the south or north, for it is said that it portends thereby that there is about to be an end of perils and alarms. Nigidius says also, that neither locusts nor grasshoppers have eyes. In snails,[31] the two small horns with which they feel their way, perform the duties of eyes. Neither the lumbricus nor any other kind of worm has eyes."

Here, again, is a passage of some historic and even ophthalmic interest, from the Book on "*Precious Stones*" (Book XXXVII, Chap. 16): "When the surface of the smaragdus is flat, it reflects the image of objects in the same manner as a mirror. The Emperor Nero used to view the combats of the gladiators upon a smaragdus." It is almost laughable, the way in which this innocent passage has been pulled upon and distorted until it has seemed to become a proof irrefutable for the existence and use of therapeutic lenses in antiquity.

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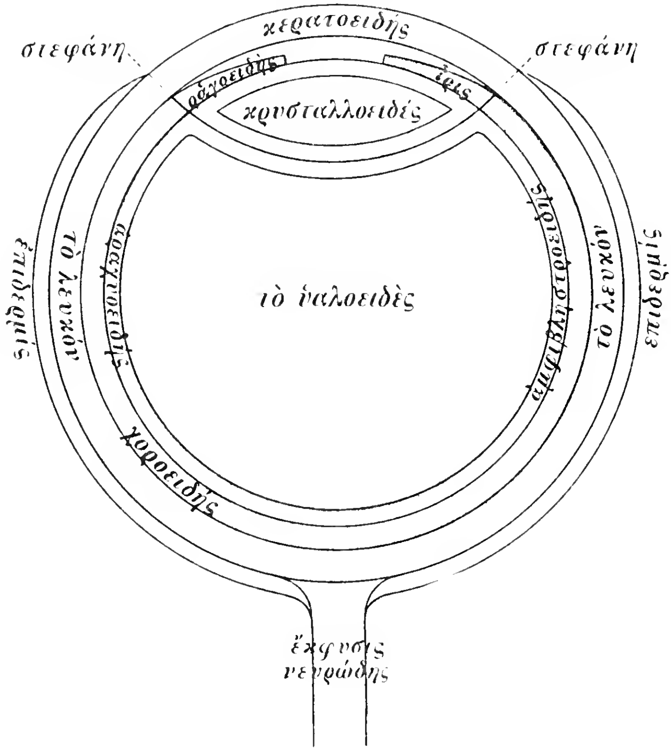
[31] How poor an observer Pliny was is plainly shown by this remark about the eyelessness of snails, grasshoppers, and locusts.

Had, or had not, the ancients spectacles and eyeglasses? or, if not these, then magnifying lenses? A war of words has waged about this very interesting and important question, a question which will be discussed hereafter in this article in connection with Roger Bacon.

It is pleasant, as a matter of contrast, to turn from Pliny, with his whimsical old-time ways and superstitions, Pliny the man of the people,



The Anatomy of the Eye, According to Rufus of Ephesus.
(As Drawn by Daremberg-Ruelle.)

to the author of the earliest anatomy which has come down to our age—Rufus of Ephesus. In order to consider this great anatomist and "first physician of his time" we shall have to return for a moment to Alexandria—to the world-renowned Museum, where, in the times of Claudius and Nero—i. e., about 40-70 A. D.—the Ephesian, Rufus, taught anatomy and practised medicine.[32] His book, entitled

[32] It is interesting to know the method which Rufus followed when teaching a class in anatomy. First he pointed out all possible landmarks on the living body of a slave. Then he dissected an ape, verifying and amplifying his preliminary statements.

"*On the Names of the Parts of the Human Body,*" contains considerable matter of interest to ophthalmologists; in fact, the earliest notice of the decussation of the optic nerves, as well as the capsule of the crystalline lens, is to be found in this old-time volume. As the most of Rufus's ocular anatomy is given in this *Encyclopedia* in connection with his biography, we pass at once to the greatest (in fact

Galen. From a Dioscoridian MS. in the Imperial Library of Vienna. (Russell.)

the only truly great) ocular anatomist and physiologist of antiquity—Claudius Galen.

Galen was born in Pergamus, Asia Minor, A. D. 131. He studied not only in his native city but also in Smyrna, Corinth, a place or two in Palestine, and, of course, in Alexandria. In the school at Alexandria he saw a human skeleton, a fact which seems to have made upon him a great impression. For a time he was gladiatorial physician in his native city, but, at the age of 34, went to Rome, where, in spite of a high degree of egotism and a very irascible nature, he soon became beyond all doubt the greatest physician in the world. He returned for a time to Pergamos, but soon went back to Rome, where

he was appointed body-physician to the Emperor, Marcus Aurelius, and, later, to Commodus. He was a true disciple of Hippocrates—whom in fact he idolized. He wrote not only on medical but also on philosophical, grammatical, mathematical, and legal subjects. The numbers of his writings on such themes amounted to 125. His medical writings were far more numerous. His most important extant works of this character are: "*De Usu Partium Corporis Humani,*" "*De Morborum Causis,*" and "*Methodus Medendi.*" His strictly ophthalmic writings—"*Optics*" and "*Diagnostics of Diseases of the Eye*"—have, most unfortunately, been lost in the stream of time. Galen not only idolized, as we have said, Hippocrates, but he was idolized himself, in turn, by all the succeeding generations of physicians for more than a thousand years. Next to Hippocrates, he is even now regarded as the greatest physician of all the ages. He died in 201 or 210 A. D.

Galen, in his capacity as general physician and surgeon, we have already discussed sufficiently in Vol. VII, in the course of his biography. We also there discussed in some detail his ocular treatment and surgery. We gave, however, to his optics, as well as to his ocular anatomy and physiology, merely the briefest summary, in order that his writings on these heads might here be presented in full—in an English translation of course.

The importance of Galen's *Anatomy and Physiology of the Eye* (in which is included his extant optics) can hardly be exaggerated. The work consists, all told, of fifteen heads, or chapters, not one of which is lacking in interest for the modern ophthalmologist. The reader, as he passes through the books, should bear in mind continually the little that was written on these heads by Hippocrates, the less that was left by Aristotle, and even the somewhat slighter amount set down by Rufus of Ephesus—in spite of the old Ephesian's very important discoveries of the capsule of the lens and the decussation of the optic nerves. The ocular anatomy and physiology of Galen (not his optics) are, in fact, the culmination, the very highest development, of these two subjects in all antiquity, and nothing of very great worth in fact was added to them for more than sixteen hundred years—i. e., until the time of Brisseau and Maître-Jan.

Galen's Optics, Ocular Anatomy, and Physiology.[33]

"Chap. I.—That it is best for the eyes to be situated high in the body and to be provided on all sides with protective apparatuses, I

[33] In the making of this translation I have followed the Greek text as given in Katz's dissertation, "*Die Augenheilkunde des Galenus,*" and desire to acknowl-

have already explained. It is further clear that the eyes should be located on the anterior surface of the body, and be directed forwards, also that two eyes are better than one. Why the sense organs are twofold and related with one another inwardly, has also been expounded heretofore, and will be explained again hereafter. If, indeed, one would only consider all these things which have been mentioned: the elevated position and the forward look, the security and the twofold nature, then it would plainly appear that the eyes could not have been placed in any more favorable position of the whole body. Should anyone complain that there are no eyes on the backward surface of the body, then he must have forgotten a matter already explained, that, namely, the sense organs require soft nerves, and that such do not proceed from the cerebellum; further, that, from the brain to each of the two eyes, processes extend, which, in their passage through the bones, are made very compact, for the sake of greater resistance. As soon, however, as these have reached the eye, they again unfold and expand, and surround the vitreous humor on all sides, like a garment, and finally attach themselves to the crystalline body. All this was described, at the very time when I declared the crystalline body to be the essential organ of vision. An obvious proof of the latter proposition are those things called by physicians cataracts [hypochymata], which come between the crystalline humor and the cornea, and which so badly prejudice the sight, until perchance a hypochyma operation is successful. The white, clear, glistening, transparent crystalline humor—only in the presence of such qualities might colors affect it—could not possibly be nourished directly by the blood, the blood which is so remote from that body in its properties, but it requires other and more appropriate nourishment. For this reason Nature created a means of nourishment more inviting to it—the vitreous humor, a substance which, on the one hand, is as much thicker and clearer than blood, as, on the other hand, it is inferior to the crystalline humor in moisture and shining appearance. For the crystalline humor is indeed absolutely colorless and moderately hard, the vitreous body, on the contrary, acts like glass which has been molten by heat. It is indeed also colorless, but its whiteness is somewhat dull and looks as if one had mixed a great deal of white with a very little black, so that the white had lost somewhat from its lustre. Through neither of these two structures runs any blood vessel. It is also clear that they are nourished by mere transferral,[34] that is to say, the crystalline humor is derived from the vitreous, this in its turn from the structure which surrounds it, and which is a process sent down from the brain.

"Chap. II.—The latter structure is called by some "the net-like membrane." In appearance it is indeed like a net, but it is not a membrane at all, either in color or in substance, but one would surely believe, if he everywhere detached this structure and laid it by itself,

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edge some indebtedness to the German translation as given in the same work—a doctorial dissertation of unusual excellence.

[34] Here Katz suggests that "diadosis" is very difficult to translate properly, and that, had Galen been a writer of today, he would have said "endosmosis."

that he had before him a detached portion of the brain. Its chief function, that for which it was sent down by the brain, is to perceive the alterations which occur in the crystalline body and to communicate them—this, of course, in addition to conducting and delivering nourishment to the vitreous humor. For this reason it contains a very large number of arteries and veins, many more and of greater size than would be appropriate to its own mass, for, with all the nerves which originate in the brain, there passes down a portion of the chorion-like meninx, provided with arteries and veins. With no other nerve, however, proceed so large vessels. Nature, therefore, is looking after not only the nerve, but also the various moist masses of the eye with respect to their nutrition. Even from the choroid coat, which surrounds the net-like structure, there proceed delicate, spider-web-like threads, which run to the retina ribbon-fashion, and carry to it nourishment. For the choroides also, throughout its whole extent, shows itself to be full of vessels—a fact implied in the name. It certainly would never have been so called, if it were not precisely a vascular complex, just like the vascular envelopes surrounding the fetus. Therein lies its proper use, and, besides, it is really a membrane, a coat and a protection for the parts lying beneath. Its place of origin is the soft membrane which surrounds the brain, and concerning which we said above that it accompanies each and every nerve proceeding from the brain, bearing with it veins and arteries. Here one must indeed admire the wisdom of the Creator, who indeed nowhere separates from the nerves their appropriate membranes, but sets the membranes close around them, for the sake of nourishment and protection, and only here, immediately after the entrance of the nerve into the eye, removes the membranes from it, and makes them as thick and hard as the dura mater, yes even much harder than that. One should, in this, carefully observe how the Creator, in similar wise, took care both of the brain and of the retina, and yet, too, with certain differences. For, that he proceeded differently from the manner employed in the case of the other nerves is entirely clear. He did not [that is to say] separate the brain from the two membranes [in the case of the other nerves]. In the case of the eye, however, he not only separated both the cerebral membranes from one another, but also these from the optic nerve. The brain part of the eye acts just like the brain, in so far as it contains veins and arteries, which weave themselves through it very completely, and inasmuch as the hard meninx stands off from it a little, clinging to the bones, but the soft meninx does not thus leave it or carry with itself vessels because of any standing off. This phenomenon should indicate the purpose of the separation. The covering, that is to say, swerves to one side by itself and is completely destitute of all vessels. Immediately thereafter, however, it appears again not less vascular than the fine meninx with a crowd of vessels which it has taken with it from all the higher regions.

"One might almost say that it had been sent to a provision market, had given off a small portion before its return, (inasmuch as it made use of the fine vessels, mentioned above, like servants) and then had

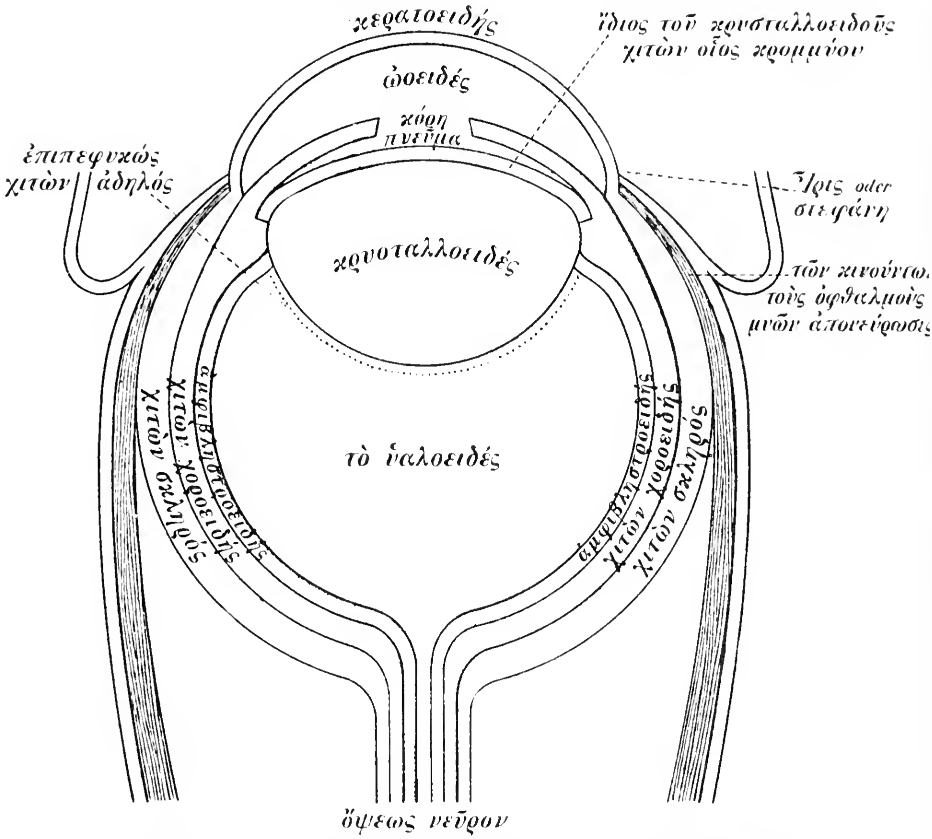
returned with what was left. It comes back, that is to say, bringing with itself a crowd of delicate, close-lying vessels, and with all in conjunction, it sets itself again on the process which comes down from above; this place of insertion appears to resemble closely the place in the eyelids where the lashes are attached. This comparison, in my opinion, is not badly chosen by those who occupy themselves with the study of natural history. Now, at the spot where it is attached, the upper process stops and goes no further, for it has performed the duty because of which it was sent forth; it unites with the crystalline body, where it can be an excellent messenger, bearing news of what is perceived by the crystalline. The place of its insertion is not without good grounds a complete circle. Since, that is to say, the just described insertion occurs on all sides of the crystalline body, which itself is round, so the place of insertion must also be round; and indeed it is the greatest circle which can be described on the crystalline—the circle which divides it into two halves. Of all unions, that is to say, with round bodies, that at the greatest periphery is the most secure, since it connects the object to be united at the largest number of points. Moreover, in order to keep the lens in its proper position on the vitreous, the circle in question must not be overpassed in a forward direction. [Next follows a brief passage which is so corrupt as to be untranslatable.]

"This last is the strongest among the membranes, and the best fitted to guard and make secure the other parts. But, even though it be sufficiently resistant to protect these other parts, it is nevertheless too weak for its own security, and not tough enough to endure without injury the hardness of its bony environment. So it is here (exactly as in the brain) surrounded, garment-fashion, by the hard meninx. In all these parts this membrane is separate from it, and is only bound to it by means of vascular connections; at the equator of the crystalline organ, finally, it is adherent. And now a fifth connection is to be added to the four of the same place—a connection which affords to the parts lying beneath it a very important protection, and which is well adapted to shield them from the dangers with which they are threatened by the bones, and which even guards them against mutual tearings asunder in case of the strongest motions. The sclera is strongly united with the choroid, this with the retina and the latter with the vitreous and crystalline bodies—being in apposition with the vitreous throughout its whole extent, and with the crystalline only along the ciliary body.[35] In this way it was possible to unite the vitreous humor, by means of these intervening layers, with the most outward lying of the membranes [the sclera, not the conjunctiva], the softest with the hardest organs, a union which Nature found possible only by means of the very appropriate inter-lamina. At the same circle comes to the eye from without, afterward clinging closely around it, a sixth membrane, seated upon the sclera. It is to a certain extent the tendinous sheet of the muscles which move the eye.[36] And, sev-

[35] Katz has here a note: "Hier ist wohl die Conjunctiva gemeint." It is difficult to see why.

[36] This I believe to be the first mention of what is now known as "Tenon's capsule."

ently, there also comes to the eye an outgrowth [37] from the periosteum, which not only unites the eye with the bones, but also serves to protect the muscles. This membrane can be seen even before the dissection. It is a soft structure, even though it be so evident, which ends at the place where all the other circles lie beneath, where, in fact, the white and the black come together. 'Iris' the place is called by those who are familiar with these matters. Others indeed call it 'garland,'



The Anatomy of the Eye, According to Galen. (As Drawn by Magnus.)

or 'crown.' When a beautiful dissection is made without the breaking through of any of the parts, a person may see the six circles, one upon the other, each different in color and thickness, so that in fact no better term could have been selected than 'iris.' [38]

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[37] By this is, truly enough, meant what today is called "the conjunctiva," although that membrane is not an "outgrowth from the periosteum."

[38] I. e., in allusion to the number of colors in the rainbow. It will be observed that "iris" is used by Galen as the name of the *region* where all these various structures come together. At times he seems to employ the word for what to us

"Chap. III.—Now, not only do the arrangements hitherto described give evidence of the Creator's wisdom, but also, and to a much higher degree, those of which we are just about to speak. For we have already, in our explanation, led to the equator of the crystalline body, the seven membranes which are placed on one another and which, at that place, are united together. What, however, now follows will carry to the highest point of admiration him who, before he hears my explication, tries to make out for himself the artistic structure. How could one in fact go better to work for the purpose, at one and the same time, of enabling the crystalline humor to become aware of the appropriate irritation, and yet also of finding itself in sufficient safety, protected from all the dangers which threaten from without. Ought it to be left absolutely naked and devoid of protective arrangements? In such a helpless condition it would not have remained unaltered for a moment, but would have gone immediately to ruin, been absolutely annihilated, being (because of its natural softness) in no condition to offer resistance to the danger which presented from without, or ought indeed for its greater security a thick protective apparatus to be set before it at this point? But the danger then would be lest by such a barricade it would be completely covered and darkened and rendered absolutely unperceptive. When, therefore, that arrangement which would preserve the accuracy of the perception, would produce a susceptibility to injury, and when some other arrangement which would protect against injury would disturb the perceptive accuracy, then, indeed, the construction of the visual organ would offer insurmountable obstacles. But Nature ought not, in such circumstances, to stand helpless, like us poor men, so she first thought out with mature reflection the best arrrangement, in order, afterward, to execute it with the finest art. When a thick and hard envelope would entail such prejudice to the special function of the eyes, while, at the same time, a soft and delicate affair would leave the eye a prey to every danger, then Nature perceived that a hard, but still very thin, envelope, if it were, in addition, transparent, would best fulfill the purpose. Always thoughtful in her work, she saw that she needed to produce the structure in question by extending forward one of the seven circles which exist at the iris [i. e., as before stated, the ciliary region]. From the four soft circles it was not possible to produce the desired membrane. Of the remaining, the external three, circles, the most external of all, the circle of periosteum, is harder by far than the four internal envelopes, but still much less appropriate for the function of protection. The circle which lies immediately beneath this [i. e., the second] requires a certain protection on its own account from its own muscles. So there remained only the membrane which takes its origin from the hard meninx, and which surrounds the choroid, and which is really appropriate for furnishing the protective

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is known as "the ciliary body;" never, however, for the diaphragmatic membrane. The word in this, the modern, sense was introduced by Jakob Winslow in 1721. Galen's word for the diaphragmatic membrane was hragoeides, i. e., grape-skin. We may also, in this connection, recall the fact that Rufus made use of "iris" to designate the *anterior surface* of the diaphragmatic membrane.

envelope. Behold then here the wisdom and art of Nature. For, as this membrane is indeed thick enough, but not sufficiently firm for her purpose, so Nature went to work to make it both thinner and stronger, and, leading it forwards step by step, she managed to render the middlemost part of it extremely delicate and yet very firm. One may best compare it with a small, thin plate cut out of horn. Therefore those who were learned in anatomy found it appropriate to give to the membrane the name of 'cornea,' an expression which has been retained even till the present day. This horn-like membrane, which, though thin, is hard and tough, must also be transparent in order to fulfill its purpose completely, that is, to let the ray pass through, precisely in the manner of finely cut, polished horn plates. Even if we were able to understand, after the fact, what Nature thought out well before the fact, should we therefore be permitted to criticise her works, and to assert that they might have been made better? I believe that the most of us would not have been able to complete them, for really such folk cannot in a single instance explain the art of nature, otherwise they would look upon it with the utmost admiration, or, if not that, then at least they would not criticise it adversely. Either one should show that a better arrangement was possible, than that which actually exists, or else he should admire the arrangement which is present. That is right and fair. Seven circles there are at the rainbow [iris]; show us then indeed, thou who draggest the works of Nature in the dust, one of these circles which would have been more appropriate, after being extended forward, to the formation of the corneal envelope. Or, if thou canst not do that, and if it does not suit thee that the cornea takes its origin from the hardest of all the coats, then show us how, if acting in Prometheus's place, thou hadst done any better with respect to the membrane proceeding from that circle. Hadst thou perhaps not made it thin and transparent, so that it might permit the visual rays to pass through it, and hadst thou, on the other hand, perhaps not made it tough, in order that it might properly and safely protect the crystalline humor? Now thou wilt indeed be silent. It is easier to rummage round afterward in somewhat which has already been created, and to inveigh against it, and to condemn it completely, than to provide everything by oneself and without blame in the very beginning. Now behold once more the further performances of Nature with greater intelligence. The corneal membrane, so tender and yet so tough, is the best protection for the organ of sight, inasmuch as it is not injured by dangers threatening from without; but it possesses three other evil properties, which follow such a structure of necessity, and which thou, O most wise blasphemer, even if gifted with Prometheus's power, would have overlooked. Verily, Prometheus himself did not overlook them, but he saw very clearly, how (first) this horn-like membrane would suffer in point of nourishment, which indeed it could not procure at so great a distance, nor could ever receive into itself bloodvessels; because of its thickness, hardness and thinness. Secondly, however, in order that it might indeed be an adequate protection for the crystalline humor against external injuries, it would itself have to be made so hard as to con-

stitute an inconvenience to the crystalline. Thirdly and lastly, he saw that it would surely disperse and annihilate the visual power which is sent down to the eye from above [i. e., from the brain]. Thou who knowest not that the essence of that power is radiant, thou who knowest not that it is injured and evaporated by immediate contact with stronger and more shining radiations, thou hadst indeed had no beautiful thought at all, hadst thou surrounded this power with so glistening a garment to its perpetual destruction. Not in this manner however, did he who created living things carry out his thought; but first he invented a plan whereby the corneal membrane might be nourished, then another for the prevention of contact between this membrane and the crystalline humor, and, thirdly, yet another, whereby the membrane in question might not destroy the light. And all these things he attained by one very simple arrangement. And that too I would explain to thee in few words, O thou hideous blasphemer of Nature,[39] if I did not well know, that thou wouldst contradict when I come to explain the act of vision. Assume that thou hast never heard anything upon the subject, even that I had not just now explained that its nature is radiant, and suppose that it is unfathomable and inexpressible, and then learn, if thou wilt, the proof through its own activity. Remind thyself how the power of sight is injured by a strong and shining ray. How the eyes of Xenophon's soldiers suffered, who had to march so long through snow-covered fields! Yes, perhaps thou knowest nothing at all about that. It would in fact not astonish me, if thou hadst never disturbed thyself in any way concerning Xenophon. I believe, too, that thou hast never heard of Dionysius, tyrant of Sicily, who caused to be erected above his prison a tiny structure, very bright and shining, being washed with chalk, or that, into this building he led his prisoners after a long confinement in the dungeon, or how those who were suddenly transported from darkness into brilliant light, looked into the splendor with joy, only to be completely blinded; for they were not in condition to endure the sudden and absolute incidence of the radiant brilliancy. But I will set aside these narratives and attempt to remind thee of that which occurs before thee every day. First, about the copyists,[40] especially when they have to write on white parchment, how readily their visual power is injured, in case it is left without protection. This they take into account in advance, laying at one side of the book colored objects, blackish and brown, and ever and again they look on these and thereby rest their sight. Then again, those who are suffering from eye diseases, are incommoded and injured by the light. They, however, can look on blue and the darker shades without suffering. Again, if a person wishes to look through clear daylight at something in the far distance, he holds his hand over his eyes and brows, or perhaps some other object, which is still larger and thicker. Then again, at the eclipses of the sun, at least the greater of these, the stars become visible for the same reason—as indeed occurred in the time of Thucydi-

39 Apparently a kind of synonym for the modern "gentle reader."

40 Slaves, of course, who, by the incessant copying of manuscripts, filled, to a certain degree, the place now occupied by printers.

des, according to the description of this author. Also, from deep wells one may see the stars, especially if the sun does not stand in the meridian. And truly, if a person should look upon the sun, without blinking, he would soon lose his eyes. And, indeed, at the eclipse of the sun, a very great many who attempted to secure an all too exact observation of the phenomenon, and therefore gazed immovably at the sun, at last became completely blind, without at first perceiving that there was anything the matter. And if thou dost not even believe Xenophon, a journey over fields of snow will teach thee how injurious such things are to the eyes. But, if thou still desirest to hear still more of an experimental nature, then take a burning lamp or any other kind of light and set it in the bright sunshine. Immediately wilt thou see how dull it looks. And if thou settest a flame, or any sort of lesser light, near any kind of great light, then the weaker ray is always overcome and dispersed by the great one. Nature, then, was not able to let the rays of the crystalline body itself be destroyed and in the eye at that, but, in order that these might be united and held together on all sides, she devised the choroid membrane, which arises from the pia mater [soft meninx] making it in many places black, in many others brownish and blue. This, now, she conducted forward from the ciliary region ['iris']at the same time with the cornea, in order that it might perform the three before-mentioned functions: inasmuch as it (first) furnishes nourishment for the cornea by its proximity; (secondly) prevents any injurious substance from coming in contact with the crystalline humor; and (thirdly) provides a more wholesome view for the visual power when this in any wise suffers. Therefore, I believe that we all involuntarily close the lids when we suffer from too bright light, thus taking refuge in an instinctive remedy. I admire especially the blue color which is spread upon this membrane. For, as this color exists nowhere else in the body, but only here, and moreover no other portion of the system appears to find it necessary, therefore it is clear to me (as indeed the entire course of my explication indicates) that Nature has created nothing defective and nothing in vain.

"Chap. IV.—Not less than the dark color of the choroid do I admire the roughness which prevails on the internal surface of the membrane which encloses the vitreous humor. Moist, soft and sponge-like, it surrounds the crystalline body so that this organ is occasioned not the slightest inconvenience by its presence. And still more do I wonder at the firmness of the external parts, at the spot where they come into close relation with the hard cornea; for it was no less requisite that no injury should accrue to the crystalline humor by the presence of this darkly-colored membrane than that the latter itself should be secure against attacks which threaten from the side of the cornea. Still more, however, I admire its perforation by the pupil. All else indeed, howsoever beautifully thought out and prepared it might have been, would have occurred in vain, if this one matter had been overlooked. However, Nature could not miss anything, this any more than another. So she produced at this spot in the dark-colored, grape-like membrane this opening. 'Grape-like' it is called (as I believe) because it was

noticed that, precisely as in the case of a grape, it was outwardly very smooth, inwardly very rough. At the place of this opening, then, there lies no other membrane between the cornea and the crystalline humor, but, as through a very thin, transparent plate of horn, occurs the meeting and the mixture of the external light rays with those which come from the interior.[41] And in order to prevent the cornea from coming in contact with the crystalline humor at any spot within the pupil, our Creator, in his wisdom drew the central portion of the cornea a trifle more forward, poured all round the crystalline body a thin, transparent liquid, exactly like the white part of an egg,[42] and (thirdly) he filled the entire place of vision with a luminous ethereal breath. This is the way, in fact, in which the matter stands. This explanation, however, requires yet one more proof, particularly because of those people who wish to establish neither purpose nor function, but consider such matters as things deeply hidden and not to be found out. At the point, then, where the cornea leaves the 'iris,' it appears to us to be very near to the crystalline body (for indeed all fluids and membranes of the eye come together here). As soon, however, as it begins to pass away from the iris, it withdraws itself ever more and more, in order to be widely removed from the place where vision is. This can be learned not only by dissections of the dead organ, but also in cataract operations on the living. For, since all cataracts develop in the space which lies between the cornea and the crystalline body, the instrument which has been introduced for the purpose of shoving the cataract aside, can be passed all about, upward and downward, forward and backward, as well as round and round, without so much as touching any of the above-mentioned bodies, so completely adequate is the extent of the interval.

"Chap. V.—That, now, a thin fluid lies between the crystalline body and the grape-like membrane,[43] while the pupil itself is filled with air, thou mayest recognize by the following facts: First, the eye in the living subject, if one observes it closely, is tense and well filled out in all directions, nowhere wrinkly and in no place slack. If, however, the eye of the dead is dissected, it is found to have become already more wrinkly than in the living state, and that before the beginning of the dissection. When, however, one cuts the cornea, the thin fluid spurts out toward him, just as, in fact, at a cataract operation, it will now and then flow out at the point of perforation. At once, then, the eyeball becomes wrinkly, contracts, and turns slack, and if now one draws away the membrane from the crystalline body and holds it away, there appears in the interval a large vacant space.[44] If, now, in the living animal, this place is well filled and holds the membranes taught, and is now, after death, empty, while the surrounding mem-

[41] A detailed examination of the different early views which were held about the nature of vision and of light, will be presented when we come to speak about Alhazen (of the Arabic Middle Ages) who was first in history to expound the matters in question with a reasonable degree of correctness.

[42] All the ancients insisted that the aqueous humor possessed the consistency of egg-white—a mistake, of course.

[43] What to-day we call the "iris."

[44] An artefact, of course.

branes have turned slack, then it is very evident that it must be filled either with air or with fluid or with both. If, further, we close one eye, while we hold the other open and observe it accurately, then we see that the pupil is open very wide, exactly as if it were blown up. And this is already clear to the intelligence, that the pupil is enlarged because it is filled with pneuma: [45] but an experiment also shows this not at all badly, establishing the theory very securely by means of facts. If one blows up the grape-like skin [*our* iris] from within, he will see that the visual aperture widens. So this experiment proves that the pupil enlarges when it is filled with air. However, even the reflection says nothing further than that the grape-like membrane, filled from within outward, stretches wide and is drawn apart and so the opening becomes wider, as is the case in all thin membranous structures, which have holes and openings and which are able to contract. So, too, in the case of sieves, the membranes have to remain tense: otherwise their pores would close. When, now, one observes that, in the living animal, both membranes [i. e., the irides of the two eyes] are tense, and that, after closure of one eye the pupil of the other enlarges, while, in the dead, even before the evacuation of the delicate fluid, the membranes get slack, and indeed, after evacuation of the fluid, fall all together, then it is evident that they must have been filled with both, with liquid and with air, so long as the animal was living. But the one ingredient, the more delicate and lighter, namely the air, easily escapes even before the opening; while the other ingredient, the liquid, remains, and can only be evacuated in a palpable manner. Also, among very old persons, the cornea shrivels to such a degree that some of these patients can see no more at all, while others see little and only with great difficulty. When one fold is placed upon another over the cornea and so the cornea is doubled and assumes an unwonted thickness, while, in addition, the pneuma is no more let down from above in an adequate manner, then of course the sight must suffer. Precisely this latter circumstance, that less pneuma is brought down from the central organ is the chief cause of the wrinkling in the area of the pupil. From all this one sees readily that all the space before the crystalline body is filled with air and thin liquid, and that the latter is to be found in all the pre-lenticular space, while the air occurs by preference in the pupil. In the aged sometimes occurs, moreover, a wrinkling of the cornea because of some senile

[45] Galen was, as to the respiration, a close follower of the school of Pneumatists. Portions of the world-soul (he thought) were continually being intaken *via* the lungs into the heart, and this individual portion of the world-soul thus inspired was supposed to be the soul of the individual. (From this view seems to have come the idea that a child does not possess a soul until it has been born and has received its first breath—a view which prevails in the United States among the laity today and which accounts for the great readiness of some of our citizens to consider feticide as a matter of no great importance.) By the heart the world-soul, or pneuma, was diffused through the various portions of the body, where, according to the region to which it was sent, it became one or another kind of "spirits." While still in the heart and arteries it was called the "vital" spirits. In the liver and the renal veins it became the "natural" spirits. In the brain and in the nerves it became the "animal" spirits, but was often referred to, even in this situation (just as above) simply as "pneuma."

alteration in the cornea itself; even in such cases, however, a defective innervation from above is a contributory cause. But yet another disease, the so-called phthisis, is only a disease of the pupil itself, which becomes narrow, while the cornea itself is not drawn into the trouble. Hence, the disease as a rule attacks one eye only, so that it may easily be recognized, and hardly can escape the physician's observation, for the eye that is sound makes more evident the faulty condition in the diseased one. On the contrary, among the aged the symptom is common to both the eyes, hence remains concealed from most physicians, for here not only is the cornea wrinkly but, in addition, the pupil is contracted. This occurs also at times when the uvea grows slack because of a diminution in the quantity of tensing liquid. However, we do not need to discuss this disease in our present consideration. That disease, however, which arises from lack of pneuma (the passage for which from above has been obstructed) and from the weakness of old age, shows us plainly that the pupil is filled with air; and one more proof of this is the fact that, on the closure of one eye, the pupil of the other enlarges.

"Chap. VI.—But is this the only object of the liquid and the pneuma, to hold the cornea as far as possible from the crystalline body and to keep it from touching that structure, or have they been created for still other purposes? As to the pneuma, it has been sufficiently proved in optics that it is luminous, and that it possesses for the functional activity of the eyes a great significance. With respect to the aqueous humor, however, one can see from the following facts that it is necessary not only for the filling out of the vacant space [i. e., the space between the lens and the cornea], but also to keep the crystalline humor and the internal surface of the iris [ῥαγοειδής] from drying out. One should bear in mind how the eyes suffer from complete evacuation of the fluid by punctures, and, further, that the disease which is called by physicians glaucoma,[46] consists in a dessication and very decided hardening of the crystalline humor, so that the eyes, in this affection, become more blind than in any other that is known. One should also consider the iris and seek to understand its nature. In truth, the part of it which touches the crystalline humor is very much like a moist sponge. Dessication, in fact, renders all such bodies hard. That is shown by sponges, berries, and the tongues of animals. If, now, this part of the uvea should become hard, it would be entirely

[46] The history of the term, "glaucoma," and its formerly allied expressions, is very interesting. Hippocrates employed not "glaucoma," but "glaucosis," meaning, probably, what is known today as "cataract." By the Greco-Roman writers "glaucoma," as a general expression, would seem to have meant "light blue." By "amaurosis" these writers understood a condition in which there was no light perception and the pupil was clear. If the pupil was bluish, the condition was called "glaucoma." If, with a change in color of the pupil, light perception was retained, the condition was called by the Greeks, "hypochyma," by the Romans, "suffusio," (by the mediæval Constantinus Africanus—whom, in this regard, we follow—"cataracta"). Rolfinck, in 1656, pointed out the true location and nature of cataract, which helped decidedly in the clarification of the ideas attached to all these terms. Then, with Mackenzie, entered in the idea of hypertonia—which, from that time until the present day, has been the essential idea of glaucoma.

useless for the purpose for which it was created. Therefore this portion must be kept moist uninterruptedly, in order that it may remain entirely moist. All these arrangements exhibit the most remarkable wisdom and skill, and by no means least the capsule which is adherent to the crystalline. For the cornea stands like a guard of defense, or a wall, ready to take to itself all the dangers which threaten the crystalline from without. But its own capsule resembles no such thing as the dry, tough peel of an onion, but is even finer and more transparent than gossamer threads, and it must excite our utmost astonishment that it does not cover the entire crystalline body, but that the part of that body which is sunk into the vitreous is completely without protection and naked. For it seemed to be better that these fluids should unite. But the part of the crystalline which is convex forwards and touches the iris is jacketed with this delicate and shining envelope. Further, the image in the pupil forms itself upon this capsule as on the surface of a mirror.[47] So Nature has provided in every conceivable way for the paramount organ of sight, not only by the proper proportion of moisture contained in it, but also by the appropriateness of the situation in which it is placed, and by its polish, and also by the completeness of its protective arrangements. The capsule which immediately surrounds it is smooth, shining, and glistening as the surface of a mirror. The membrane which is nearest to this is vascular, soft, black and perforated. Vascular, in order to provide the cornea with abundant nourishment; soft, in order to be able to touch the crystalline body without injuring it; black, in order to gather the light together and lead it to the pupil; perforated, in order to permit the radiant pneuma to pass on outward. The membrane which stands the farthest out of all, a guard and shield for each and every one of the others, is thin, transparent, and hard as horn. Thin and transparent, in order to permit the visual ray to pass; hard, in order to be a certain protector. Shall I now rest satisfied, or had I better proceed to express my praise concerning the form of the crystalline body? That body, in fact, is not symmetrically globular, though Nature, as a rule, prefers the globular form, and is most familiar with it, for reasons which I have often indicated. The body in question would not have been sufficiently secure, had it been made exactly spherical. For, had it been given such a form, it could not so well have received the circle [terminating, as Galen supposed, the retina] at the site of the ciliary body, and would also have been in danger, whenever the eye was subjected to stormy motions, or vigorous blows, of sliding out of the vitreous humor. For the apposition and the adhesion is less secure in the case of entirely round, than for flatter,[48] bodies, since the former moves upon a vaulted and therefore slippery surface. This is therefore fundamental for the form of the crystalline body. So, then, every part of the eye appears to be made sufficiently secure, even as far as to the protection of the cornea, which is itself an organ

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[47] A curious mistake for a man like Galen, inasmuch as the slightest observation of a facetted, or otherwise imperfect, cornea, would have shown the true location of the image in question.

[48] Katz has here ''glattere,'' for ''platytérōn''—perhaps a typographical error.

of protection. This indeed is placed the most externally of all, set as an outpost against all injuries, smoke, dust, cold, heat, and contusing or incising objects. It takes its origin of course from the hard meninx [dura mater]. In this way our Creator, in consideration of its noble nature, has set this structure of necessity before all the others, because he possessed no better material for the purpose. Nevertheless, he made it secure on all sides with lids and lashes, and the encircling bone and skin. The lashes he placed the forwardmost of all, in order that these might serve, in a manner of speaking, as a palisade, which should intercept small objects and by their hairs prevent such objects from falling into the open eye. The lids, also, which are able by coming together to close the eye, he placed well forward, as a protection against larger bodies. And against the impact of still larger objects, he placed above the eye the brows; below it, the cheek; at the wider canthus, the nose: at the narrower, the forward-arching malar bone. Surrounded on all sides by these arrangements, which catch the force of all the larger bodies, the eye can suffer no harm, and, in addition, there is the great mobility of the skin, which contributes not a little to the protection of this part. For, by drawing together from all sides, it presses the eye together inwardly [backward], and so compels the organ to occupy the smallest possible space. Then, further, as it has the faculty of folding itself together at the same time as the lids, so it catches first of all the force of whatever objects may have got past the protective curvature of the bones, and so, but for this, would penetrate to the eye. It is struck first, it is first threatened by danger and first suffers from it. Next in order come the lids, which are struck, cut, torn, and injured in all other possible ways, precisely as if they were shields, which had been set up before the cornea. Of what material, now, could such shields best be made? Of something soft and fleshy? Then they would be more easily wounded than the cornea itself, and would be anything else than a protection. Or should there have been selected for the purpose a hard, bony substance? Then they would have been but slightly mobile, and could not have touched the cornea without injuring it. Therefore the only proper way was to make them from some material which, while very hard, nevertheless was of such a nature that it could be moved about with ease, and also could touch the cornea without endangering it.

"Chap. VII.—It is also well that the lids are adherent to the bones and also to the eyes themselves. And inasmuch as this must have been kept in mind in their construction, as well as, still more, their ready mobility and resistance and their innocuous approximation to the cornea, therefore it is right and proper to give our admiration to Nature, who here has created everything so beautifully that no one can imagine a more complete arrangement. She extended, that is to say, the so-called periosteum,[49] from the arching of the brows forward, and carried it as far as to the borders of the lids. Then at the under portion of the lids she carried it backward, without, however, contrary to what many suppose, throwing it into a reduplication, like the hide of a doubled

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[49] Periostion. The conjunctiva, of course, of the present day.

shield. Then she carried it, not indeed from the place in which she had started, but united it with the underlying muscles which move the eye, and conducted it thence to the region of the ciliary body, where she caused it to unite with the cornea. The space between the two periosteal layers [conjunctival cul de sac] she has strewn with fatty, slimy masses, and, in addition, there are here to be found a few membranes from the expanded muscles.[50] Here also arise sometimes the so-called hydatids, when, that is to say, the fatty bodies, which Nature created in order to render the eyelids supple, have attained to an extraordinary size. In a way very similar to that above-described, the lower lids arise from the periosteum of the upper jaw, these structures then being carried forward to a certain distance and also being carried backward to the cornea. At the point where the periosteum [understand again, conjunctiva] begins to turn over, there spreads a mass which is harder than a membrane, the so-called tarsus. It holds, closes, and ties together that vaulted place, which is produced by the duplication of the membrane [*fornix conjunctiva*]. For this purpose it was created, and yet, in addition, it serves two other ends, concerning the more important and wise of which I shall speak very soon, while, of the less important, I shall make an end here and now. The tarsus is, then, perforated by a few small holes, from which the lashes run forward, which have a firm hold in the toughness of the tarsus, and, by virtue of the same quality, are enabled to keep a straight direction. For, although it was proper to place the hairs of the brows one upon another, it is, on the other hand, better to have the lashes straight and so to preserve them throughout their entire extent. For the purpose because of which they were created, that double purpose, they can best fulfill by the actual, present arrangement, inasmuch, that is to say, as the hairs of the brows catch up everything which drips down from the forehead and the head, before it can fall into the eye, the lashes, on the contrary, keep the dust and sand and the tiny winged insects from falling into the eye, without, at the same time, themselves producing an injury to that organ. So one must again admire Nature very particularly, inasmuch as she directed the lashes of the lids neither toward the cheeks, nor, indeed, inwardly toward the eyes. In the first case she would in fact have missed the object for the sake of which these structures are present, and, in the other case, they would have been a hindrance to the eye by rendering it impossible to perceive objects in their continuity in the visual field. What more? Is not the precisely correct interval at which the lashes stand from one another a wonderful thing? If they stood farther apart, then many, many things would fall into the eye, which now are kept away from it. If, on the other hand, they touched one another, they would very much darken the vision. That, however, they may not do, just as little as they may leave out of account the primary purpose for which they were created.

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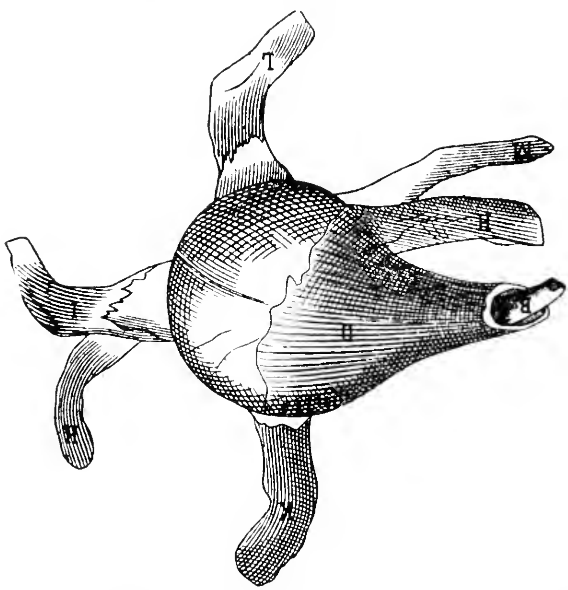
[50] Concerning this clause, Katz remarks, "Der Text ist hier sehr zweifelhaft." True, but it is hard to resist the conviction that the keen-eyed old Pergamene had discovered a goodly portion of Tenon's capsule, even the forward-passing fibres from the muscular sheaths.

"Chap. VIII.—Now that we have described the lids, and so have ended with the eye itself, it is time to tell in what ways we are enabled to effect the various ocular movements. A creator who was wholly unacquainted with the elementary principles of sight, or else who was careless, might have thought it best to leave the eyes idle and wholly devoid of motion. But nothing could remain unknown to him who has shown so much wisdom and cleverness in the entire construction of the animal anatomy, nor was he able to neglect the smallest matter. What, then, are the principles of vision which he must know, and how did he come to know which of these were best. The eyes cannot, in any one position, perceive all visible objects, as perhaps the ears can hear every sound. Anything which stands at either side, behind, above or below, or, in fact, anywhere else, excepting in a straight direction before the pupil, cannot be seen. If, then, the eyes were absolutely immovable, and could only see straight forward, we should merely be able to see the smallest amount; hence, the Creator so made the eyes that they could move in all directions, and, in addition, he made the neck also very mobile. To the same end he made two eyes, which stand at a not inconsiderable distance from one another. Those who are blind in one eye do not see objects which lie in front of this eye, even when the eye is very close to such objects. If, then, the eyes should be so created that they can move themselves voluntarily, and if all such motions are effectuated by means of muscles, then it is clear that the Creator must surround the eye with muscles. We, however, must not merely establish their necessity, but we must individually enumerate them, and call to memory their size and arrangement. As the eye has four kinds of motions—one, namely, which draws it toward the nose, therefore inwards, another, which directs it outwards, toward the lesser canthus; a third, toward the brows; a fourth, finally, which causes it to look downwards, towards the cheek—so there must, as a matter of reason, be an equal number of muscles to produce these movements. And indeed there are two on the sides, at each canthus one, and two others, of which one is above, the other below. At the point where they run out into tendons, all the four together form a complete circle, a broad tendon, which terminates in the region of the ciliary body. Moreover, as it was well to have the eye capable of rotating, Nature added to the others [the recti] two oblique muscles, one on each lid, which extend from above and below to the lesser canthus. So, by means of these muscles, we are able to direct the eyes in any desired direction. And yet one more muscle is present, which surrounds the rest of the eye, and which encloses and protects the soft nerve at its place of entrance.[51] It lifts [retracts] the eye, at the same time drawing it upward and rotating it. The optic nerve would indeed be easily torn, whenever reached by falls on the head, were it not well anchored on all sides, as well as surrounded and protected

[51] The *retractor oculi*, or *musculus oculi choanoides*, a muscle which occurs neither in apes nor in men, but which is actually found in the larger herbivora. For a full explanation of the way in which the usually accurate Galen came to commit so gross a mistake as to assume the existence of this muscle in the human subject, see **Choanoides**.

in all other possible manners. If we have a patient with a protruding eye which still sees, we may assume, if the disease arose without trauma, that the optic nerve is dragged upon, because of a paralysis of the muscle, which is not in condition to hold it back properly and to surround it. If, however, the eye no more sees, then something has happened to the nerve itself. When the eye, in consequence of a heavy blow, leaves the orbit, while the visual power is preserved, then the muscle is torn; if the visual power is lost, the nerve is torn also. For this purpose is the muscle present, to secure the eye at its root. To some anatomists it appears to consist of three parts, others consider it a double muscle, regarding certain tendinous origins and



A Drawing by Vesalius, Showing Especially the Choanoides Muscle.

insertions as divisions of the muscle. Of whatsoever number of parts one regards it as consisting (whether two or three) the purpose of the muscle is single—that, namely, which we have just stated.

"Chap. IX.—These are the arrangements provided by Nature in the construction of the eye, both in the matter of size and in that of completeness. There yet remains one matter which is not less worthy of admiration than all the things of which I have spoken heretofore. That is to say, the lids must be susceptible of motion at will, or they would have been useless. For all voluntary motion Nature created muscles, which produce the motions by means of tendons which are adherent to the parts. It has already been shown by us, in the division on the movements of the muscles, that all parts susceptible of voluntary motion require at least two antagonistic muscles, one which extends and another which flexes, that one and the same muscle cannot produce

both motions, because it always draws toward itself the part to be moved, and that, finally, merely one position of the part can be produced when only one muscle is present. If then, that is true, how can the lids be moved? The under lid is really immovable; the upper lid, however, is plainly seen to move. And, as certain sophists can neither find the muscles which move the lid, nor are able to explain how otherwise the motions could occur, they proceed so far in their shamelessness as to assert that the motions of the lids are by no means voluntary, but absolutely involuntary, even as the stomach, the intestines, the arteries, the heart and many other organs, exhibit independent motions, absolutely unrelated to the will. They believe, namely, that one had better lie than confess ignorance. When a person lies concerning such small matters, the fact escapes the observation of most men. But when we all see the bright sun above the earth, and some one declares that it gives no light, and there is no such thing as day, then we take that man for crazy. Moreover, will any one assert that, in walking, we do not move the legs voluntarily, but involuntarily and unconsciously? Such a person appears to us to have suffered in his understanding no less than the first. For, if any one can move his legs faster and slower, and indeed cease walking entirely, or, if he like, resume again, would there be any man who is still in his senses, who would declare that this activity was involuntary and unconscious? If, now, it be impossible, when once we have closed the eyes, to keep them closed as long as we like, and again, whenever we please to open them, then to close them again and so on, always according to our will, then is the motion of the eyes truly not our work. If, however, we can do all this unhindered, as much and as often as we like (assuming that the lids are in their natural condition), then it is clear that the motion of the upper lids is dependent on our will. Nature would, in fact, have given these structures to us in vain were we not in condition to close them against an object coming toward them, and which then would strike upon and injure the eye. However, it is not necessary to wonder at such assertions, seeing that they come from persons who regard their reputation for sophistry as more important than their reputation for truth. Their very shamelessness, in fact, contributes not a little to exhibit the works of Nature in all their magnitude. When we see plainly the motion of the upper lid, but do not know how this is brought about, nor are able to discover the musculature which is essential to such motion, what, then, in all the world should we have done, had we, in the place of Prometheus of the myth, been obliged to create the animal kingdom? I believe that we should surely have left the upper lid without motion. Perhaps, too, such persons would say that they would have caused muscles to grow from the brows into the eyes, and to take an insertion into the entire cartilage of the lid. But, in that way, O clever people, the entire lid would be inverted and crumpled up and drawn toward the brows. Even that, however, we will now let pass; it will, let us say, be able to open very well of itself. Even then, however, tell us how it will be closed. For one could not extend a muscle from the lower lid and attach it to the tarsus [of the upper]. That would be absurd. Nor could one have a muscle

proceeding from internal parts to be attached to the upper lid. For, indeed, it would not be possible, in that way, to close the lids; they would be inverted inwards, clapped together and folded up, whenever they were drawn upon by such a muscle; and, further, the muscle itself would have taken a very peculiar position; it would have compressed the eye and would have been compressed by it, and would have been all crushed together and hindered in its motion. One must, therefore, in my opinion, wonder at the sophists, who neither discover anything at all of the works of Nature, nor, on the other hand, accuse Nature of lack of skill. They should have been obliged to say, I think, that it were better had the eyes no lids at all, or that they must have lids, movable or immovable, voluntary or involuntary, and that, for this purpose, muscles must, in some manner, be added unto them. But they, indeed, in their wisdom, have gone so far, that they, although the motions of the lids take place with perfect plainness, are not able to fathom how it can happen, or imagine any other kind of motion. They are too stupid to see a genuine artist in him who thought this all out and created it. When a contest takes place among architects, as to the way in which a house, a door, a couch, or any similar thing, can be most fittingly arranged, and, while all the others have no advice to offer, one of them arrives at the correct idea, then, of a truth, he will be admired, and be taken for a skilful and experienced artist. But the works of Nature, which we (I will not say, could not have thought out in advance, but) are not able to explain fully in a single instance when they are present before us, should we not indeed marvel at these as greater than all human achievements? However, let us for a time pay no attention to the sophists, and let us see what there is in the movements of the lids that is worthy of admiration, mentioning first of all the things which the best of our predecessors have thought concerning them. It has already been stated that, beneath the skin which covers the lids, are delicate membranes. With these I will begin my explanation. These membranes exactly cover the muscles which move the lids, very small muscles, and they themselves are held taut by the aponeuroses of these muscles which are attached to the tarsus. The tarsus itself, we have said, is cartilaginous, and is attached like a ribbon to the membranous substance which forms the lid. But, on that occasion, we did not go on to explain that it receives the smooth, delicate processes of these muscles. That you may now learn, so hear that one of the muscles, which, at the greater canthus, extends obliquely toward the nose, is attached to the half of the tarsus which lies on this side, while the other muscle, also an oblique one, but to be found at the lesser canthus, proceeds to the other half of the tarsus, namely the one which is nearest it. When the first-named muscle acts, it draws down toward the nose the part of the lid pertaining to it, while, when the other acts, it lowers the remaining portion of the lid. For, as the origin of the one muscle is at the greater canthus, and that of the other is at the brow, and as all muscles exert their force in the direction of their origin, so, of course, that portion of the lid which lies the nearer to the nose must, of course, be lowered, while that which stands adjacent to the lesser canthus is elevated. When, now, with

equal power, each of the muscles draws upon the lid, then that portion of the lid which is nearer to the lesser angle is elevated, while the other is depressed, so that the eye is no more closed than open. Such a lid is called by Hippocrates 'bent,' and he places it among the signs of a serious disease. He calls this turning of the lids also by a special name, 'ίλλωσις. This condition is observed when both the muscles are attacked by cramp, and draw on their respective portions of the tarsus. When only one of the muscles functionates, drawing the lid toward itself, while the other remains at rest, the result is that the entire lid is either opened or closed. That is to say, it is always the case that, whichever portion of the tarsus is drawn upon, this draws the other

The Muscles of the Upper Eyelid, According to Galen.
(As Drawn by Magnus.)

portion of the tarsus along with it. This is due to its hardness; if it were membranous, fleshy, or soft in any other way, then the portion that is drawn upon would not necessarily be followed by the other. This, too, Nature, in her wisdom, beheld in advance, making the tarsus, therefore, hard and cartilaginous, as she gave it to the lid, afterwards attaching to it the ends of the two muscles. If you take a bent stick and pull upon it at any point, the whole stick follows. And this is also the case with the tarsus: it, too, follows the tug of each of the muscles. That is the third most important and most useful property of the tarsus, the description of which I had also undertaken. Such, then, are the properties of the upper lids.

"Chap. X.—Why, now, has the under lid no motion, seeing that here it would serve just the same purpose as in the upper lid, while an equal space is present here in which muscles could be placed? In this respect indeed Nature appears to have acted improperly, inasmuch

as she could have made over to each of the lids half of the total motion, and yet gave all of it to one—this in addition to the fact that she made the lower lid very much the smaller. Precisely as in the case of the ears, the lips and the wings of the nose, so both the lids should have received equal size and motion. But the deviation is here due to the situation. For, had the under lid been made longer than it really is, it would not have been so firm, but would have had to wrinkle and fold and become slack, and, worst of all, there would have been collected within it the gum, the tears, and various similar matters—substances which would have been difficult to remove. So it was better for this to be made small, for thus it is always tightly compressed against the eye, and fitted to it, lying exactly upon it, thus being able to evacuate all the secretions with ease. Possessing such properties, it had no need of motion. Here, in the case of the lids, the best anatomists appear to have recognized fully the skill of Nature and to have expounded it properly. I should agree with them absolutely if I were really certain that I had seen the muscle at the inner canthus. Until the present moment I have not been able to see the muscle distinctly either when treating in a surgical manner the aegylops [lacrymal fistula] when, of course, one not only incises the part, but, oftentimes, even burns the whole region deeply so that splinters of the bone which lie beneath, detach themselves—and yet the under lid is by no means prejudiced in its motion. Hence, the matter seems to me to demand investigation. If ever I become clear on this point, then I will express myself about it in the book on unexplained movements which I have in mind to write. Thus far I can only say that the wisdom of Nature is so great that, although it has been investigated so long and so often by men of very great ability, it has not by any means been discovered in its completeness.

"Chap. XI.—Next in order is a consideration of the ocular angles. If the fleshy body [sarcodes soma, our lacrymal caruncle] which lies at the larger angle, or canthus, is of any use, then Nature appears to have treated the little structure very badly, inasmuch as she withheld from it the necessary protection. If, on the other hand, it has no purpose, then Nature has mistreated the greater canthus, inasmuch as she provided it with unnecessary ballast. What, then, is really the case, and how is it that Nature has done an injustice to neither of these two structures? She placed the fleshy body [caruncle] at the greater canthus as a protection for the opening which passes to the nose. The purpose of this opening was twofold. The first we have already explained, when describing the cranial nerves; it is now full time to explain the other. Through these openings there flow down to the nose all the secretions of the eyes, and, sometimes, not long after the employment of medicaments in the eyes, the patient spits them out or blows them from the nose. For, at the same place where the canal runs from the canthus to the nose is to be found the connection of the nose with the mouth. Therefore, when a person blows his nose, the fluid comes from the nostril, and, when he spits, it comes from the mouth. In order, now, to prevent an overflow at the corner of the eyes, and to protect us against continual epiphora, the so-called

fleshy bodies [sarcóde sómata] were placed above the openings. Consequently, they prevent anything from flowing over at the canthus, and direct everything into the openings which have been provided for it. The best proof of this conception is the various acts of malpractice, committed so often by persons who style themselves ophthalmologists. Some of these persons, that is to say, when destroying by means of caustics the so-called pterygia, the large roughnesses [tà megála traxómata] and the fig-like growth [kaì tàs sukósis] and the callosities [kaì toùs túlous] of the lids, destroy also at the same time, without taking note of the fact, the tendinous caruncle. Others, again, when removing by operation the tumors of this region (the so-called encanthides) take away more than is necessary, and so produce an improper running away of the fluids. This application they then call 'the flowing' (rhoiáda). Need I say more about such an absurd proceeding? Nature has thought all this out very wisely, and besides has placed very fine openings in the lids, a trifle outward from the greater canthus, which go to the nose, and which take up and give back a watery fluid in accordance with the requirements.[52] Their value is not to be lightly estimated, for, when an excess of fluid is present, they carry it away, and, on the other hand, when the eye is lacking in moisture, they bring the fluid back again, in order to render it possible that the motion of the lids shall be properly preserved. Dryness beyond moderation, that is to say, makes the lids harder and therefore inflexible and less mobile, while an excess of moisture makes them weak and soft. A middle condition is the only right one for all bodies with respect to their natural activities. In order to render possible full ease of movement, there are, in addition, two glands in each eye,[53] a lower and an upper, which, through perceptible openings, cast moisture upon the eye, exactly as the glands at the root of the tongue pour saliva into the mouth. That Nature also surrounded the eye with fatty masses for no other than the same purpose, is proved by their stability. For, as these melt only with difficulty, they protect the eyes by acting precisely like a salve.

"Chap. XII.—We have now spoken of almost everything concerning the eye, except one single matter, which indeed I had rather not describe at all, so that neither the difficulty of the explanation nor its length might cause me to be hated. For inasmuch as I, in connection with this matter, must touch upon mathematical theory—an unknown subject to the majority of educated persons, and one which makes even adepts therein hated and unacceptable—I had therefore rather not begin a discussion of any sort or kind about this ocular point. As, however, a dream came to me and complained that I had badly conducted myself toward the most divine of the organs, and had even

[52] It is really strange that Galen should have committed the error of supposing that moisture is carried up to the eye *via* the lacrymo-nasal canal, as well as down from it, for, as presently appears, he understood thoroughly the existence and functions of the lachrymal glands.

[53] The earliest mention, so far as I know, of the lachrymal glands. The discovery of these structures is ordinarily attributed to Nicolaus Steno (also written Stenson, Stenonis, and Stenonius), 1638-1686, but surely the sharp-eyed Pergamene is entitled to the credit.

committed an outrage against the Creator by omitting a work which so plainly exhibited his highest wisdom and providence for living things, I was obliged to take up a subject which, until then, I had completely neglected, and to give it some attention. Those nerves of sense, which, leaving the brain, proceed to the eye, and which Herophilus calls canals (because they are the only nerves in which the paths of the pneuma can be distinctly seen) possess not this peculiarity alone, but also distinguish themselves from all the other nerves in this, namely, that, although they arise from widely separated portions of the brain, they begin to approach each other on their journey to the eye, finally blending, only, however, to separate once more and go their several ways. Why, now, did not Nature cause them to arise from one and the same spot, and why, when they had once arisen, the one on the right and the other on the left, did she not lead them in a straight line to the region of the eyes, instead of first bending them inwards, uniting both them and their canals, and only then permitting them to go to the eyes, each on the side of its respective optic tract. She, in other words, did not weave them together or exchange the one for the other, carrying the right nerve to the left eye, and, reversely, the left nerve to the right eye, but she gave to these nerves a figure which closely resembles our letter X. If one did not prepare his specimen well, he might believe that they really crossed each other and ran one above the other. That, however, is not the true state of affairs, but, as soon as they have touched each other inside the skull, uniting their central canals, they separate immediately, as if to show simply and solely that they only came in contact in order to unite their canals. What such an arrangement is good for, and what purpose it serves, I will now explain, following the command of the divinity. But, first, I will turn to such of my readers, as have studied the auxiliary sciences, especially geometry, and who therefore know what a circle is, and an axis, as well as similar matters, and will ask them for a moment to be patient, and to permit me, because of the preponderance of ignorant persons, to explain the meaning of these names—which I will do in the briefest manner possible. When we have won these mathematical conceptions, then we shall add the optical explanations, in order to end our task with the utmost promptness. Supposed, that one of the two eyes is gazing at a circle. 'Circle' I call such a figure as stands in every spot at an equal distance from its middle point. The fellow eye should be closed. From the middle point of this circle, which is called the 'center,' let there be conceived a straight line running as far as to the pupil which is looking at it. This should be, I say, not an angular line, or a bent one, but one like a thin hair, or spider's thread, passing from the pupil to the center of the circle—therefore absolutely rectilinear. Further, let us suppose that there are, in addition, a multitude of lines which pass from the pupil to the line which bounds the circle (which is also called the 'periphery') these also perfectly straight, like thin gossamer threads, each made tight in its turn. Then we will call the figure which is bounded by these lines which run straight to the circle, a 'cone,' the pupil being the apex of the cone,

the circle its base. The line running straight from the pupil to the middle of the center we will call the 'axis.' It lies in the middle of all the other straight lines, therefore in the middle of the cone itself. If you already know what a convex and a concave surface are, then you can easily imagine a mean between the two, that is, a 'plane,' which is neither arched nor hollowed. 'Plane' is what we will call the upper surface of this space. Further, we will imagine a millet grain, or other small body, to be placed upon the axis, which extends through the air from the pupil to the circle's center. Then the center of the circle will be, as it were, covered, and the pupil prevented from seeing it. When a person once understands this, he will easily perceive that every object which is brought between the eye and any body which is gazed upon, will obscure that body, and will render impossible its perception by the eye. As soon, however, as it is taken away, either entirely or merely moved to one side, then the center of the circle will be visible again. When one understands that, he will also easily comprehend that every object, in order to be visible, must be free from all obscuration—that is, nothing must lie on the straight line which may be conceived as running from it to the eye. If one keeps this in mind, one will easily perceive that it is not without reason that mathematicians have constructed the proposition that all vision occurs in straight lines. We will, then, in the future, call these straight visual lines and the delicate gossamer threads which run from the pupil to the periphery[54] of the circle, not 'spider-threads' but 'visual lines,' bearing in mind that the periphery of the circle is seen by virtue of these lines, and the center by virtue of one other line, that one, namely, which runs in the axis of the cone, and that the entire upper surface of the circular area is seen by virtue of a still greater number of lines which run to it from the pupil. All those visual rays which stand at equal intervals from the axis, and which reach the same given plane, we will call 'correlated visual rays,' the other lines, however, the 'uncorrelated.' Now, O reader, thou wilt, I think, incidentally have perceived, how it is that the rays of the sun, having passed through a narrow opening, and pressing on farther forward, are nowhere moved aside or bent, but follow precisely along a path which extends rectilinearly. Now, then, imagine that such is the path of the visual rays. When thou hast made all this clear to thyself, whether thou hast understood it immediately, or hast been obliged to return to it again and again, in order to understand it, and if thou now really knowest the matter very well, then pass to the following part of this writing. Learn first of all, however, this principle, namely: that each and every object which is to be perceived, is never seen baldly by itself, but that always something is seen by the visual rays which surround it, and which proceed, at times, to some body on the thither side of the object which is looked at, at times also, however, to some object on the hither side. The second of the principles is this: That an object which is seen by the right eye alone, will, if it be close, appear to lie more to the left, if, however, it be far, more

[54] Mistranslated by Katz "Kreiscentrum."

to the right; while, obversely, an object seen by the left eye, will, if close, seem to be more to the right, but if far, more to the left; while an object beheld by both the eyes appears to stand in a mean, or average, position.[55] And, thirdly, one must also know that, if the pupil of an eye is pressed upon and shoved upward or downward, then that appears to be double, which, previously, exhibited itself as single. Such readers, now, as occupy themselves with mathematics, and readily comprehend what has just been explained, may permit me, for the sake of the multitude, to express myself fully concerning each of the three just mentioned points.

"And first I will speak about the first proposition: That every object is seen together with others. Let us suppose that the pupil

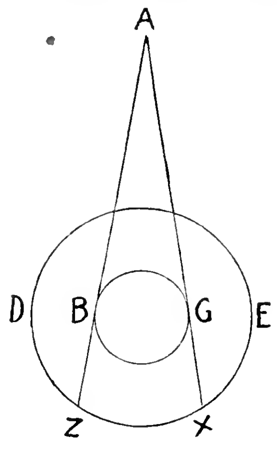


Fig. 1.

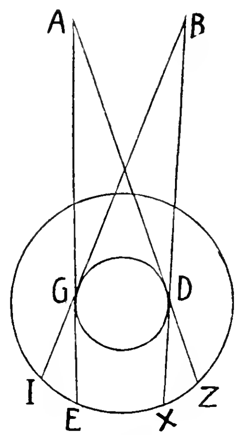


Fig. 2.

is at A (Fig. 1), the area of the object looked at to be BG; while the visual rays proceed from the pupil A to both the points BG—along the straight lines AB and AG. On the other side of the area BG, should lie DE. Then let the rays AB, AG, be extended until they intersect DE at ZX. It is clear, now, that, while BG is seen, ZX is not. And, therefore, ZX is precisely so covered that it can absolutely not be seen at all. The areas, however, which lie at each side of it, DZ and XE, are seen lying next to BG, and BG itself also, of course; so that, we may say that BG is seen in fact together with each of two other areas. This is, then, the explanation of the first of the three propositions.

"As to the second proposition: That an object never appears to stand in the same place when it is seen by one eye, as that in which it appeared to stand when seen by the other eye, and that, when seen by both the eyes, it always appears to stand in yet a different place from that which it seemed to be in when gazed upon by either eye

[55] Because, of course, seen by the "cyclopic" eye of Hering.

alone; in other words, that an object is seen as if in one place by one eye, as if in another by the other eye, and in yet a third position by the two eyes acting conjointly. I will now explain this proposition.

"Let the right pupil be at A (Fig. 2) the left at B, the area to be looked at GD, and let rays proceed from both pupils AB to GD, and then be carried on farther than GD. GD will now be seen by the right pupil exactly in the direction of the area EZ, by the left pupil in that of XI, and by both the pupils, acting conjointly, in the direction of EX. So that neither does the one eye perceive the object in the same place as that in which the other eye beholds it, nor do both the eyes together see it where it seems to be when seen by either alone. If, now, there is any person who cannot follow these diagrammatic proofs, such a one can easily test our proposition in his own person by an experiment, and so convince himself by the evidence of his senses. If he will stand near a column, and close first one and then the other eye, then he will find that there are certain parts which he just now saw with the right eye on the right side of the pillar, which he cannot see with the left eye, and, likewise, that, on the left side of the column, there are things visible to the left eye which are not to be seen by the right. But if he has both eyes open at the same time, he will see both sets of objects. For a larger surface is hidden when we look with one eye only, than when we look with both. Every visual object appears to lie in a straight line with any other which it completely covers, so that everything which is still visibly adjacent, appears to be situated either to the right or to the left. Therefore only those objects which are not seen lie in a straight line with the object looked at. But other parts were visible to the right, still others to the left eye, so that even the situation of the surface which is looked upon appears to be special to each of the two eyes; and there is visible in common for both the eyes, all that which had not been seen by either of the two eyes specially. Therefore, also, an object which we see simultaneously with both eyes hides less than if it were seen with one, no matter which the fixing eye may be. If, now, a person goes a little farther away from the column, and opens and closes alternately each of the two eyes, and looks at the same time toward the column, then this appears suddenly to change its place—on the closure of the right eye to the right, on the closure of the left eye to the left. If one opens the right eye, the column appears to move to the left; if the left eye, then to the right. To the right eye, in other words, the column appears to lie to the left; while to the left eye, to the right. If both eyes look, the column appears to stand in the interval between the positions which it appeared to have when first the one eye, then the other, was looking. If now one gazes in the same way at a star, or at the moon, especially when it is full and uniformly round, then it has also the appearance as if it moved immediately toward the right, whenever one opens the left eye, while closing the right, and it appears, correspondingly, to move over to the left when the experiment is reversed. That we receive this impression is plain to anyone who has made the experiment, but how it happens and why it has to happen, is shown by the construc-

tions given above. Further, if one so turns an eye that the pupil is directed downward, the object observed appears to lie lower, but, if he so turns the eye that the pupil looks upward, then the opposite appears to take place. This, too, one may determine for himself by means of an experiment. But the reason for these phenomena, a person cannot discover without our explanations made above. For, if the axes of the visual cones lie not in one plane, then, of necessity, the object looked at must appear to the one eye to lie higher, to the other lower. For the eye which has the higher-lying axes, has also the whole cone placed higher: that cone, however, which falls from the lower-lying place out upon the visual object, has also all the rays of the same arrangement placed lower, and the cone from the higher-lying place, the opposite. If, now, the object which is seen by the higher-lying rays, appears to lie higher, while the other, that of the lower-lying rays, appears to lie farther below, then it is of course clear that, to the higher-placed cone, the visual object appears to lie higher, to the lower-placed cone, however, lower. [The reverse, of course, is the truth.] One may get a manifest proof of this if he will look at the auxiliary, or secondary, image, which appears when one eye is shoved a little out of place, after the confinement of that eye together with the other. Absolutely singly, that is to say, does the appearance of the position of the object formed, which the now closed eye possessed, when it was open. The other remains unchanged, retaining the position which it held before. Indeed, when both, in their ordinary activity, see just one object, the apparent position of the object (on the closure of one eye) immediately changes, and the object seems to move sidewise, and, on the opening of the eye, it takes at once another place; thus it will indeed never remain at the same spot, whether one closes the one eye or the other. If now for those who have pressed the pupil up or down, the one image of the position is entirely lost, while the other remains unchanged, if such persons close one of the two eyes, then it is not every distortion of the pupil which makes the object double, but only the distortion which carries the pupil unnaturally far upward or downward. The distortions toward the smaller or larger canthus cause the object to appear more to the left or the right, but absolutely not doubled, for the axes of the visual cones in this way remain in the same plane. Those who squint, either by an acquired anomaly or from the earliest period of fetal life, never commit any errors in the knowledge of objects looked at, for, in such cases, neither of the pupils stands higher than the other, but the fault consists only in this, that the one eye looks too much toward the nose or else is directed away from it. But those persons whose pupils are turned too far upward or downward have a very disagreeable disease, for they must always bring the eyes into the same position, if they would see accurately. Every object, then, is seen in its place in consequence of the circumstance that the sense of touch, guided by the sight, does not deceive or deviate from distinctly perceived objects. This is proved chiefly in this way that one may easily pass threads through the finest needles, he who has been deprived of one eye as well as he who sees with both eyes—which could not be done if one

did not have an exact discrimination among the objects seen. Since, then, as has been explained, every object is seen by the side of some other, it is clear that a given object, with respect to these other objects which surround it, appears to lie now to the right, again to the left, and, finally, on some other occasion, straight out before the looker, and so the assertions do not contradict one another. There exist innumerable other proofs for the theory of vision, which cannot here be adduced. For not of my own accord did I write this chapter, but, as stated, at the command of a divinity. It alone will know whether or not, in this work, I have preserved a seemly proportion.

"Chap. XIII.—We will now end the book by reminding ourselves again that the axes of the visual cones must lie in one and the same plane, in order that what is single may not appear double. These axes, now, have in our body, as a point of departure, the canals which come from the brain. These canals, then, as early as the time when the living being is yet in its mother's body and is still in process of formation, must be constructed in one and the same level plane. How, now, must this plane (which may be inclined) be constituted in which Nature, when creating the living being, erects the canals? Should it be a hard membrane, or a tunic, or a cartilage, or a bone? A soft organ, indeed, which yielded to adjacent bodies, would not be securely fixed, without bending. And how would Nature have constructed this organ, and how would she have distended it with the two canals without its being subject to compression? That such an arrangement in this place was not easy to hit upon, those understand exactly who have occupied themselves with dissections. Moreover, I do not say this, that Nature could not have found some kind of way for the origin and placement of this structure, so that it would neither have injured the neighboring structures nor have been injured by them, had it been absolutely necessary to do so and had it not been possible to complete, in another extremely simple and easy way, the construction of the two canals in a single plane. What, then, is this simplest and easiest manner and method, which from the beginning until now it has been our task to describe? It is the bringing together of the two canals. For two straight lines which intersect in any common point (which, so to speak, form the vertex of their angles) lie in one single plane, even though, on either side, they extend to infinity. And any straight lines uniting at any points whatsoever *these* two straight lines (which extend themselves who knows how far?) must lie in the same plane as those two also, for which reason every triangle must lie in a single plane. If, however, any person does not comprehend that of which we have just spoken, then it is clear that he does not understand at all the elementary principles of geometry. It would take me too far, if I attempted to give also an explanation of these elementary conceptions, and they who are not already educated in many things would not even comprehend the explanation. Euclid proved in the 11th Book of his 'Elements' that of which I now speak, and, in that book, it constitutes the second principle, which, condensed, is as follows: 'When two straight lines intersect they lie in one plane, and every triangle is placed in a single plane.' The proof, O reader, thou must learn from

Euclid, and when thou hast learned it, thou mayest come again to me, and I will then show thee on the living animal the two straight lines, the canals, that is to say, which come from the brain. Each of these, again, proceeds to its own appropriate eye, as was said above, and, constructed like a net, it betakes itself in spherical form as far as the border of the crystalline body, enclosing the vitreous, so that the pupil and the whole root of the eye lie in one straight line, that, namely, in which the nerve itself commences to resolve, and, thirdly, in addition to these, the union of the optic nerves in the anterior portion of the brain. It is here that they begin to move along one single plane and to condition the position of the entire ocular apparatus, and to render impossible that either of the pupils should lie higher than the other. [It is, however, the rule that one of the pupils lies higher than the other.] Therefore it were truly well to have had the nerves which bestow upon the eyes their visual perceptions to proceed from a common point of origin.

"Chap. XIV.—Why, then, did Nature not create for both [the nerves] one single origin in the brain, but caused the one to proceed from the right half, the other from the left, then brought these two together, and caused them to unite in a median position: this is next in the order of discussion. It was not possible to cause to proceed from this place, I do not say such large nerves as each of these two is, but not even much smaller ones. For the infundibulum, which was described in a former book, and which encloses within itself the canal which purifies the brain, lies here, and it was truly impossible to place it elsewhere better—the structure whose function it is to pour out the secretions in their entire mass into the throat. For the same reason it was also impossible either to place elsewhere the canals which extend from the brain to the nose, or to displace their points of origin to other portions of the brain. For, as the nose stands in the middle of the face, it follows that the canals which pass to it should be placed in the middle of the anterior portion of the brain. Since, now, it was not advantageous to set these canals elsewhere, likewise the infundibulum, and since the nerves could not proceed from the middle part, it is clear that it was better for the remaining part to cause them to arise on both sides, and to cause them to come together in the same place, after they had run forwards for a little distance. One more most admirable work of Nature with respect to her architecture wilt thou learn to know. O reader, which I have thought better to describe in the sixteenth Book, which is on the anatomy of the nerves. I executed the command of the divinity, and not in vain, because, for some, the explanation will be of use, when once mankind has shaken off indifference—a trait which now they exhibit regarding the most beautiful things. It were also perhaps not without advantage to adduce the views of the ancients on the union of the nerves. Some say that the nerves were first bent inwards and then again outwards, in order that they might not be subject to any kind of injury occurring in a straight line, others are of the opinion that it was done in order that the nerves might mutually communicate their perceptions, and in order that whatever the one might suffer in the way of injury

should be shared by both. Others again said that the sources of all sensations must be referred to one place of origin. These, now, would have said the truth, if only they had asserted that the visual activity must be referred to one place of origin, and then had shown the extent of the mischief which would have followed if this were not the case; the foregoing explanation, then, is not my invention. Now, however, where they assert, and assert correctly, that the chief place of sensation, which receives all sensations, must be one single place only, they nevertheless believe that it was precisely for this reason that the soft nerves unite—a matter in which they are deeply in error. The organ which receives all sensations must be the brain;[56] otherwise, a person must accept that neither the nerves of the ears and of the tongue, nor those of all the other parts of the animal body, lead back to their place of origin. And further to accept that the nerves come together in order to share their sensations—that would be an assertion which would be directed against the provision of Nature, who had in mind something precisely opposite, as has been so often said. For it is better, when at all possible, that no part should be affected by the sufferings of another. Whoever believes this explanation to be correct can put it to use, precisely as in the case of the proposition which says that the nerves would be easily torn, if they had extended in a straight line. Me it does not entirely suit. For indeed the nerves which go to the stomach and which are drawn down by the weight of that organ, would, it is true, often be torn, had they not previously been wound round the esophagus. The canals, however, which pass to the eyes, would never be subjected to anything of the sort, for the eyes never possess any such weight as the stomach, which is often filled with food and drink, nor do they occupy any such variable position, nor are they, moreover, so far removed from the place of origin of the nerves. And even if one of these things were truly correct, even then the muscles which surround the [optic] nerves, and even before them the process from the dura mater, which in the case of no other nerves presents such thickness and hardness, would serve for ample protection. For, before coming from the skull, the nerves have nothing to suffer, as little in fact as the brain itself, which, moreover, is so uninterruptedly jarred, and as little as the outrunners which proceed to the nose and which are so extremely delicate and soft and extend so far. This very intelligent reasoning may, as I have said, be made use of by anyone who wants it. I, for one, who did not place much confidence in it, and who was convinced that nothing was ever done by Nature vainly, sought most assiduously for the reasons for this peculiar arrangement of the nerves, and I believe that I have found them, all the more that they seem to one of the divinities to be worthy to be written down. Before I experienced his command (for whosoever calls upon the gods must speak the truth), I would not mention this reason, precisely in order not to be hated by the majority of my readers, who would rather stand anything than betake themselves to geometry. I intended to enumerate the three views above mentioned, and to recognize as the most plausible that one which declares that the course of the canals

[56] Hippocrates, it will be remembered, thought the brain simply a large gland.

is oblique in order that these structures may not be torn, and then to add, for the sake of truth, that it were better to have the innervation [pneuma] which proceeds from the brain to either of the two eyes when we close or have lost one of them, to go in its entirety to the other eye. For then, as the visual power would be doubled, the eye would of necessity see better. And that seems to be what actually occurs. For, if any person holds an object between the eyes, upon the nose, lengthwise—a board, say, or the hand, or anything else—in such a way that both the eyes cannot at the same time see any object situated on the one side or the other, then such a person will see indistinctly with each of the two eyes. If, now, he closes one eye, then he sees much more plainly, as the visual power which, until then, had been divided between the two sides, now proceeded entirely to the one eye. I desire only to mention this purpose of the union of the canals, a purpose which, in truth, exists. As I have already demonstrated times innumerable, Nature has created certain things for a principal purpose, certain other for auxiliary purposes. And so here the most important and most necessary purpose, that of preventing objects in the external world from appearing double, while the above-mentioned use is secondary. A god commanded me, as I have said, to write down the first purpose also. He knows how I have kept far away from whatever was unclear. He knows also how I have avoided not only this point but, in many other places of my commentary, such voluntary explanations as touch upon geometry, astronomy, music or other of the speculative sciences, in order that my book might not become an absolute abomination to physicians. In the course of my life I have made the observation ten thousand times that people who gladly met me because of my professional activity among the sick—a matter in which I appeared to them to be possessed of great experience—avoided me absolutely and took no pleasure at all again in meeting me, as soon as they learned that I had wandered in the fields of mathematics.[57] For this very reason I have always guarded myself against touching upon such themes, and only here, as I have said, following the command of the divinity, have I resorted to mathematical theories.

"Chap. XV.—Perhaps some one will now take me at my word, asking how then it comes that if, of my own free will, I have omitted many things, still the treatise is complete, inasmuch as I have never failed in any part, to point out purposes, in some cases, verily, stating not merely one purpose alone, but several. To such a person the comprehension of the matter will soon come, and he can even be convinced by that which he himself has adduced. For, if our creator is so wise that the works created by him exhibit not one purpose only, but two or three or even still more, then it is not difficult to lay aside several of the least intelligible purposes out of the great heap. Thus, when, above I was describing the crystalline body, I adduced one purpose

[57] No doubt the truth. And the pathos here, even after more than seventeen centuries, is still to be plainly perceived. How often, in fact, at the present day, the laity is deeply suspicious of educated physicians, preferring all manner of half-trained, or wholly untrained, pretenders!

for its shape, but then omitted the first and most important purpose thereof, because, for its proof, [geometrical] constructions were necessary. Now, however, that purpose also shall be declared. For, as I was once compelled to speak concerning the principles of optics, the following explanation cannot be in the least obscure. As objects are seen in straight lines (by the crystalline body through the perforation in the iris by way of which that body comes into relation with the objects of perception) then it is clear to any one who remembers the former explanations, that a sphere comes into such relations by fewer of its parts than does a body which is flatter. If any one still does not understand that, I will make it clear by means of diagrams. Let the diameter of the pupil, which is a complete circle, be AB, the diameter of the crystalline humor GD, the part of that humor which is turned toward the pupil GEZD, and there should be drawn from the pupil the lines BE, AZ, which touch the crystalline humor. It is now clear that the part EZ will communicate with the perceptible objects, that, however, the portions GEZD, lying at both sides will come into contact with visible objects by none of their parts whatever. Were the crystalline body less convex, then a greater portion thereof would come into relation with the outer world, inasmuch as tangents include a smaller part of completely curved bodies than they do of bodies which are somewhat flattened.

"We will now assume that the crystalline body has become flatter, that the part turned toward the pupil is GDXI, and again let there be drawn from the borders of the pupils the lines BX, AI. The section XI will communicate with external objects, and there will be cut off from such communication merely a small part on both sides of the tangents.

"If, indeed, the crystalline body were actually a plane [absolutely flat], then it would communicate with the external world throughout its entire extent. We have, however, demonstrated that this structure must be round, in order to be safe from injury. This work, too, of Nature, should be admired, inasmuch as the organ was not merely made round, but was also so conformed that it would come into relation with perceptible objects by the majority of its parts.

"These, then, are the matters which concern the eyes."

So much for the optics of Galen, as well as his ocular anatomy and physiology, two extremely important, if elementary, subjects, which, with him, attained to a condition of development which prevailed almost unaltered for sixteen hundred years. The ophthalmic pathology, therapy and surgery, however, of this old master of medicine, though valuable indeed, was not by any means so exceedingly remarkable—nor did the condition of developemnt to which it was carried by Galen prevail for anything resembling so extremely long a period. In fact, at the very outset of the middle ages we shall find, in Aëtius of Amida, a writer of greater importance by far than Galen—with respect, of

course, to these three subjects only. We shall therefore mention very briefly—

Galen's Ocular Pathology and Treatment.

Pathology.—The causes of the various symptoms in the eye relate to—

I. The essential organ, the crystalline body.

II. The brain and the visual nerve (for the visual power proceeds from the brain to the eye by means of the visual nerve).

III. All the portions of the eye other than the crystalline body.

I. The diseases of the crystalline body correspond to the eight dyscrasiæ. (Recall, in this connection, the pathology of Hippocrates.) The structure can also undergo a solution of continuity, and can be dislocated. If it be dislocated to the right or to the left, the evil is but slight. If, however, it be displaced in an upward or downward direction, there results diplopia.

II. Likewise, the brain and optic nerve exhibit diseases, which correspond to the eight dyscrasiæ, and these parts, too, can suffer solutions of continuity.

III. "The affections of the various other portions of the eye occur (chiefly) when, either in the pupil or in the space between the pupil and the crystalline body, pneuma or liquid so comports itself as to hinder the perception of objects by the crystalline body. It can also happen when that portion of the keratoidea which lies before the pupil becomes abnormal, and in inflammations of the conjunctiva, chemosis and pterygium. It can also occur, again, in consequence either of enlargement, diminution, distortion or rupture of the pupil. Once again, the aqueous humor may be either increased or diminished, as well as thickened and discolored, and so produce disturbances of vision. Thickening of the aqueous produces inacuity of vision, as well as shortsightedness. If the thickening be complete (as happens in hypochyma) the vision is wholly shut off. If the thickening correspond to a portion of the pupil only, then the patient sees as distinctly as ever, but not so many things at once, because of the narrowing which has been produced in the cone of visual rays. If tiny thickened bodies, unconnected with each other, swim round in the aqueous humor, they produce in the patient an optical illusion, as if, in the outer world, gnats or flies were floating. If the aqueous humor has been darkened, then the patient sees as if through fog or smoke. If the aqueous be changed to any other color, then that color seems to be diffused throughout the external world. Among these cases should be grouped the

optical illusions which occur in consequence of a beginning hypochyma, and which have to be distinguished from similar illusions produced by vapors from the stomach.

"Finally, the patient may be affected by disturbances of the innervational pneuma. If the pneuma be abundant and clear, like ether, then the subject sees into the farthest distance and also very exactly. If it is only scantily present, but pure, he sees near by exactly, but distant objects not at all. If it be abundant but moist, he sees far but not exactly. If moist and scanty, he sees neither clearly nor far.

"Treatment.—*Foreign substances* should be removed, but nothing which naturally belongs to the eye, and which has simply been corrupted. A *pterygium* is of a nature foreign to the healthy eye. It is, however, not so plainly foreign as a *honey-tumor*. The larger sort of *water blisters* [cystic tumors] are to be treated by operation, the smaller, however, by drying remedies. The *chalazion*, on the other hand, is, in its very nature, an abnormality, and so should be removed.

"A *cataract* can, in the beginning, be dispersed, but not later.

"Among the oculists of our day, a certain Justus has cured numerous patients of their *hypopion* by shaking their heads. He places the patient upright on a chair, grasps the head on opposite sides, and shakes it till the pus runs down before our eyes. It then remains below because of the heaviness of its substance. On the other hand, a cataract does not remain below [i. e., after it is couched] unless one carefully fastens it down.

"However, there are exceptions. A few cataracts are of a more whey-like consistency, and, when these are depressed, they at once break up, and, a little later, settle down as a sediment.

"When, however, we wish to dissipate pus in an eye, we have to resort chiefly to the collyria containing myrrh. Next in efficiency come those containing frankincense.

"Often I have evacuated the pus at once by means of a puncture in the cornea, just a little above its border."

The remedies for *conjunctivitis*, he says, must, of necessity, belong to those of the general class which are used in inflammation elsewhere —but not so strong. Astringent remedies, therefore, should be mixed with milk, decoction of goat's horn, or the white of egg. The milk should be from a young and healthy woman. He then proceeds to speak of "one-day collyria"—which certainly sounds well. These contain copper filings, annealed copper, saffron, myrrh, catechu, castorium or frankincense, while those which are known as "barm-colored" contain an abundance of gum acacia. Baths in a decoction of melilot and goat's horn are also prescribed.

For *ulcers* he recommends especially the flowers of zinc, advising the inclusion of mandragora juice when pain is especially to be combatted. One remark sounds very much like a sentence from a twentieth century textbook: "The chief aim of the treatment is to keep the ulcer clean, for the nature of the parts will of itself fill out the excavation and lead to cicatrization."

For *pterygium* and *trachoma* he advises "purifying" remedies.

His treatment of severe trachoma is very interesting and hardly to be improved upon at the present day: "In severe cases of trachoma physicians have, in their perplexity, thought out a singular remedy, namely, having everted the lids, to cleanse them thoroughly and then to scrape them off without the application of drugs. A few scrape only superficially with a small sharp spoon against the scalpel and afterwards wipe up with a soft sponge that which flows away, and then adstringe the lids as far as any roughness remains. Others employ also the superficially rough skins of certain sea-animals in a manner entirely appropriate for this purpose. One of my teachers even prepared an eye-pencil of pumice-stone, and, having everted the lids, rubbed the roughness away from them with this instrument. As a matter of course, a person must pulverize the pumice-stone, and make it into a pencil with tragacanth or gum. When, under the employment of the pencil mentioned, the discharge begins to cease, then we may venture to rub into the lids purifying medicines; but, at first, we should employ only a weak solution, and later, when it is found that the patient bears this well, we should gradually strengthen it."

It is readily seen that the ocular treatment and pathology of Galen, though in certain points they show a decided advance over those of Celsus, do not begin to exhibit the vast improvements which were effected by the ever-dissecting Pergamo-Alexandrian in the subjects of anatomy and physiology. Moreover, as stated, we shall find, in the very early Middle Ages, one Aëtius of Amida, who, though far inferior to Galen in optics, ocular anatomy and physiology, was yet unquestionably his superior in all the other branches of our art.

Before, however, we leave antiquity, we shall have to consider three more men—each of whom possesses for our history a modicum of importance—Antyllus, Marcellus Empiricus and Oribasius.

Antyllus was a distinguished physician of the third century, concerning whose life almost nothing is known. Though he seems to have written a very great deal, only a few brief fragments of his works have come down to our time. He it was who invented the "Antyllic operation for aneurysm," still in use.

Ophthalmologically, Antyllus is of some importance, because he has

been repeatedly said to have been the inventor of cataract extraction. This, however, as Hirschberg has shown, is indubitably a mistake. The former opinion rested not on any extant passage from Antyllus, but on an obscure quotation made by Salah ad-Din from Rhazes. It is possible that certain physicians of antiquity really attempted the extraction of what we call a cataract—as to this we cannot be absolutely certain. However, it is more than probable that all that was ever extracted *via* the anterior chamber of an eye in all ancient times was simply what we call hypopyon. The suction method of removing cataracts from young eyes, as we shall see hereafter, was invented in the Arabic middle ages by one Ammar, or Omar (born in Missoula, he practised in Egypt), while the extraction of senile cataract was introduced, as everybody knows, by Daviel in 1748.

Marcellus Empiricus was not a follower of Hippocrates, but of the "ista, sista" school of medicine, the school, that is to say, which, setting aside the necessity for observation and induction, relies on ignorance and magical formulæ. He was born at Burdigala (now Bordeaux), in Gaul, 345 A. D., and, in spite of his ignorance and superstition (or, perhaps, as the very result of these qualities) arose to be chief apothecary and master of the household *(magister officiorum)* to Theodosius I. He therefore must have exercised much influence in the world of medicine.

About A. D. 410 he compiled a dispensatory for the poor, entitled "*De Medicamentis.*" The substance of this work was taken chiefly from Scribonius Largus, but its author added much new matter of a magical and superstitious kind. It consists of 28 chapters, or divisions, of which the eighth, devoted to ophthalmology, is entitled "Ad Omnes et Multiplices Oculorum Dolores Collyria et Remedia Diversa, etiam Physica de Probabilibus Experimentis." The whole book closes with a poetical epilogue in 78 lines.

Oribasius, though not an original investigator or writer, was yet a man of scientific education, and a follower of him of Larissa. Born at Pergamus, 326 A. D., he studied in Alexandria, settled in Athens, and later was body-physician to Julian the Apostate, in Byzantium. He died in 403. Oribasius is useful because of his very extensive compilations from numerous excellent authors, some of whom are only known today because of their preservation in his amber. In his "*Medical Collections,*" "*The Synopsis*" and "*Household Remedies*" are to be found a number of ophthalmic passages, which need not here detain us.

And so, with a number of humble compilations, arrives the end of the great Second Act of the ophthalmologic drama, an act which began with the immortal successors of the immortal Hippocrates, and which

later brought before us men like Aulus Cornelius Celsus and Claudius Galen.

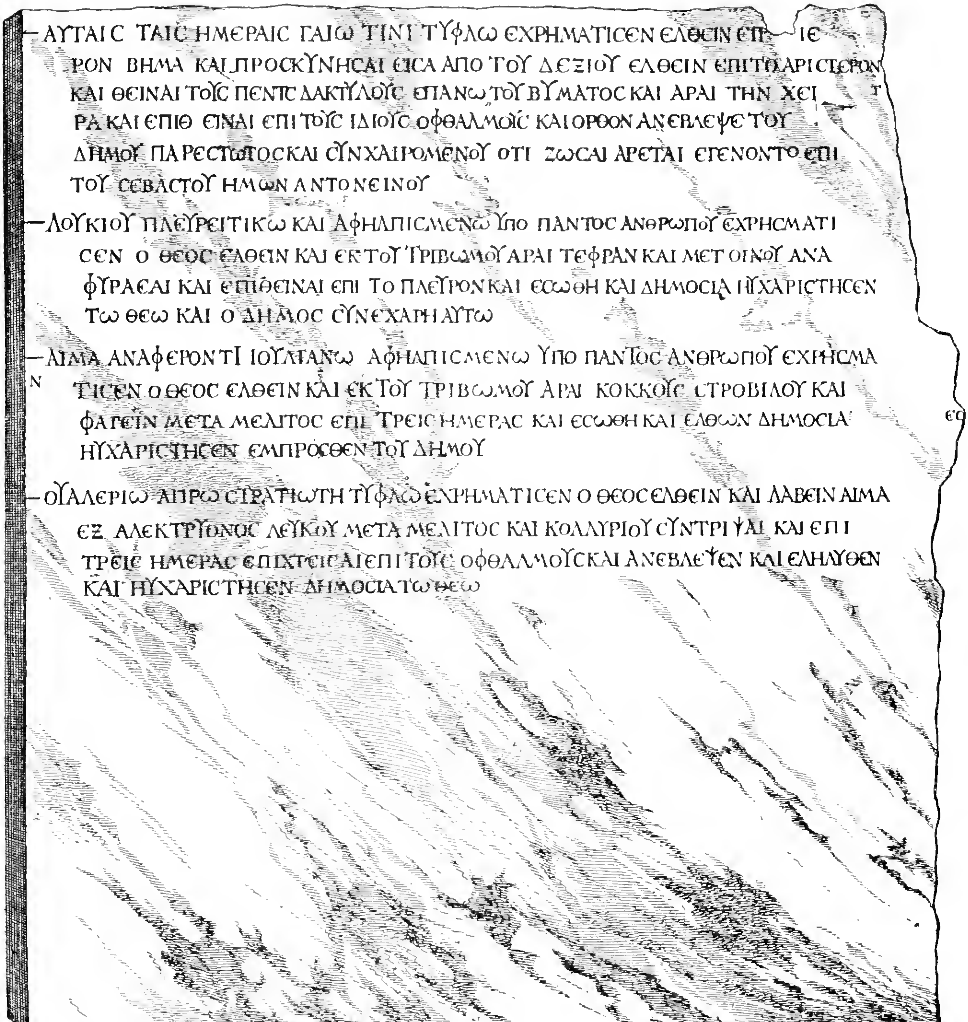
Before, however, we pass to the middle ages, we can do no better than consider, for a moment, the conditions under which medical, and especially ophthalmologic, practice, was carried on in the Rome of Celsus, Rufus, Galen, Antyllus and Oribasius.

Medicine here, as in Hippocratic Greece, was partly rational, partly superstitious. Thus, the cult of Æsculapius had been transferred to Rome from Epidaurus in 291 (293?) B. C., for the purpose of averting a pestilence. The god himself was brought, it was said, embodied in a serpent of very great size. As soon as the ship, which was bearing the large snake up the Tiber, arrived in sight of the Tiberine isle, his snakeship left the vessel, swam to the island, and there hid. As a consequence of this, the island was ever after deemed to be sacred to Æsculapius, a temple in his honor was built upon it, and the portion of the island which was turned down stream was revetted (as far as the Pons Cestius at least) with a wall of tibertine in such a fashion as to cause this portion of the island to resemble the poop of a ship. As at Epidaurus and at Athens, so, too, here, the sick resorted to the Æsculapian temple for instruction about their diseases. Apparently, however, there was never a hospital on the island, or even on the main land in any way connected with the temple in question.

A part of the quasi-trireme wall is still in existence, along the west side of the island, and votive tablets which had been left in the temple by those who believed themselves to have been cured or benefited by the god's advice, have also been recovered. Here are two of special interest to ophthalmologists: "At this time a certain Caius, who was blind, received from the oracle the advice that he go to the altar and call upon the god, then, passing from left to right, that he lay upon the altar five fingers. He was then to draw the hand back, and touch the eyes with it. And he saw again immediately, first of all the people who stood about him rejoicing. This happened in the time of the Emperor Antoninus."

In the time of the Emperor Antoninus (86-161), as the reader will readily see by comparison, both Celsus and Dioscorides, as well as Rufus of Ephesus, had come and gone, while Galen himself was thirty years of age when this good old sovereign died. So there would seem to have been but little excuse, at the time, for the existence of theurgy and superstition. After all, however, the public of today is but little wiser, even after the coming and going of Hunter, Jenner, Lister, and Pasteur, as well as St. Yves, Daviel, von Graefe and von Helmholtz. But this is all another story, which will occupy us later.

The second of the votive tablets runs: "A blind soldier, Valerius Aper, was advised by the oracle to make a collyrium from the blood



Marble Votive Tablet, Found in the Tiberine Temple of Aesculapius at Rome.
(The first and fourth inscriptions are ophthalmic.)

of a white cock, and to rub this in for three days. Seeing again, he came and praised the god publicly."

Physicians in ancient Rome were almost invariably and at all periods Greeks. The gift of the Romans lay toward politics, administration,

law. Their ability, in fact, was executive, not scholarly or artistic. Hence, the only medical writing of importance which has come down to our day and which was written by a Roman is the "*De Medicina*" of Celsus.

In the time of the Republic, the better classes among the Romans took medicine for a trade and held it in great contempt. Only Greeks or slaves would practise it. The attitude changed, however, when Julius Cæsar granted citizenship to all physicians, who were permanent residents of Rome. It changed still more when Antonius Musa succeeded in effecting a cure of the great Augustus by means of applications of cold water, after the case had been declared to be incurable. Musa was given his freedom, the citizenship of Rome, the rank of knight, and a very large sum of money.

In the time of Galen, there were slave physicians, freedmen physicians, and physicians who had been born free. Physicians in the narrower sense were called *medici;* surgeons, *chirurgi* and *vulnerarii.* There were also court-physicians *(palatini)* who were under the direction of a chief physician *(archiater,* or *dominus medicorum).* The latter, upon retiring, were known as *ex-archiatri. Archiatri populares* were city and district physicians, who practised medicine privately, treated the poor for nothing, and lectured on surgery and medicine. All the *archiatri populares* of any one city were united in a kind of guild *(ordo)* called the *collegium archiatrorum.* Admission to the college could only be had by the vote of a majority of its members. No legal requirements for the right to practise medicine existed anywhere.

Physicians mostly practised in the so-called *medicinæ*—first-floor offices, or shops, which were open to the public street. In the rear were an extra room or two, for private cases. Some physicians, when not engaged in treating or examining patients, would stand at the door of their offices and cry their merits to the passing public. Rare and expensive drugs, beautiful surgical instruments, wonderful specimens of pathologic products, and similar articles were freely exhibited on counters to all the passers by.

Physicians, for the most part, both prepared and dispensed their own medicines. Sometimes, however, they wrote prescriptions, which, it seems, must be in Doric Greek—which reminds us, of course, of the present fashion of writing prescriptions in Latin. *Pharmacotritæ* were persons whose independent occupation consisted in the preparation and sale of powdered drugs. *Pharmaceutæ* prepared and sold drugs of all sorts, and also engaged in a certain amount of counter-prescribing. *Pharmacopolæ* sold drugs, put up doctors' prescriptions, and

often traveled around from city to city, pretending to a learning and skill which they did not possess.

Specialists abounded, as a matter of course—obstetricians, dentists, herb-doctors, milk-doctors, wine-doctors, gynecologists, masseurs, specialists in fistulas and fractures, genito-urinary specialists, uroscopists, venesectors, aurists, and last but by no means least—ocularii, or oculists. By far the great majority were oculists.

The oculists got good fees. Charmis received for a single cure the equivalent of about $10,000.00. P. Decimus and many others left large fortunes.

Nothing is known of the course of study which oculists especially pursued, if any. They practised mostly, like all physicians of the time, in the open shops, or *medicinæ*. When, however, a patient could not come to the doctor's shop, or office, he would send a message by a slave, and the doctor would take his box of medicines and instruments—a gorgeously decorated affair, with, often, a silver statuette of Apollo surmounting the lid—and traipse off afoot, or ride in a slave-borne litter, on his errand of mercy or money, as the case might be.

And so we have come to the end of antiquity. Already the Roman Empire had been divided (A. D. 395) within the life of Oribasius—the last of the line of the ancients. Then—in 476 A. D.—came the fall of the Empire in the West, the event which is generally taken to constitute the boundary-line between that grand division of history which is called "antiquity" and the next, which is known, variously, as "the Middle Ages," "the mediæval period" and "the thousand years of darkness."

During all these thousand years, the spirit of Hippocrates, and of his great son, Galen, were in danger of being extinguished absolutely.

III.—THE MIDDLE AGES.

Act III of the great ophthalmologic drama (which corresponds in time to the mediæval age) is the critical portion of the play. Already, before the beginning of the Middle Ages, the science of the Greco-Roman world was in a depressed, in fact a depraved, condition. But now, in this, the third division of our history, the melancholy state of affairs appears to grow ever worse and worse. Not only were the middle ages ushered in by the Fall of the Empire in the West (which presupposes a tremendous inroad of European barbarians) but, moreover, in 622-732, an immense invasion of the civilized world occurred from Asia—the Saracenic, or Arabian, invasion—an irruption which threatened, like an enormous wave of ignorance and savagery, to over-

flow, to overwhelm, forever to extinguish the dim torch of science. For awhile it appeared that all the lore of all the earlier ages must be forever lost. The outcome, however, of this unexpected influx of barbarians over Africa, over Palestine, over Syria and Persia and almost all the more learned lands of Europe, is one of the most charming chapters, or, say, scenes (to keep the figure going) in the history of our subject.

The mediæval period is conveniently divided into: (1) The Byzantine Middle Ages. (2) The Saracenic Middle Ages. (3) The Western Middle Ages. Inasmuch as the classification is made on a geographic basis, it is no great wonder that the different periods lap, chronologically, or, rather, almost coincide. In order that the reader may have a clue to the treatment of this division of our subject, we here subjoin a list of the men whose work is to be considered in each of the divisions mentioned.

A. The Byzantine, or Greco-Roman Middle Ages. (502-1400 A. D.) (Geographical parts more especially concerned: Byzantium, Asia Minor, and, to a less extent, Rome.)

Names of workers.	Life dates.
Aëtius of Amida	502-574.
Alexander Tralles	525-606.
Paulus of Ægina	625-690.
Leo	9th century.
Theophanes Nonnus	10th century.
Joannes Actuarius	14th century.

B. The Arabic, or Saracenic, Middle Ages. (850-1375 A. D.) (Geographical parts more especially concerned: Arabia, Persia, Syria, Egypt, Spain.)

Names of workers.	Life dates.
Halaf at-Tuluni	Flourished 900 A. D.
Rhazes	850-932
Haly Abbas	Died 994.
Tabari	Fl. 975-1000.
Ammar	Fl. 1000.
Albucasis	D. 1013.
Avicenna	980-1038.
Ali ben Isa	Fl. 1000-1035.
Alhazen	965-1038.
Zarrin-Dast	Fl. 1050.
Abenguefit	998-1074.

Names of workers.	Life dates.
Avenzoar	D. 1162.
Averroes	Born 1126.
As-Samarqandi	D. 1222.
Halifa	Fl. 1275.
Salah ad-din	Fl. 1285.
As-Sadili	Fl. 1375.

C. The Western Middle Ages. (1050-1519 A. D.) (Geographical parts more especially concerned: Italy, France, England.)

Names of workers.	Life dates.
Constantinus Africanus	Fl. 11th century.
Master Zacharias	Fl. 12th century.
Benevenutus Grapheus	Fl. Middle of 12th century.
Petrus Hispanus	Fl. 13th century.
Arnold of Villanova	1235-1313.
Roger Bacon	1214-1294.
Guy de Chauliac	1300-1368.
Leonardo da Vinci	1452-1519.

It will have been observed that the Saracenic Middle Ages began about four centuries later than did the Byzantine, and the Western Middle Ages two centuries later still; while, in the matter of terminations, the period of Byzantine science and that of Saracenic science, ended almost simultaneously, while the Western period ran on in its feeble way until the Renaissance, when suddenly it expanded into the modern period, and then, returning to the ancient East, whence all its strength originally had come, it now is repaying its debts with manifold usury, in Syria and in Egypt, in Mesopotamia and in Persia. More than this, it is spreading its magical bounties over lands to which it never was anywise indebted—India, China, and Japan, and over even two (if not three)[58] enormous continents of which Hippocrates had never dreamed.

A.—THE BYZANTINE MIDDLE AGES.

To begin with the Byzantine Middle Ages—the immediate continuation (ophthalmologically at least) of antiquity. The earliest man of the period is Aëtius of Amida. This somewhat slavish, but most exhaustive, ophthalmologic compiler was born at Amida (now Diarbekir) A. D. 502 and died about 575. Educated at the University

[58] Depending on whether or not Australia is regarded as a continent.

of Alexandria, he very soon settled in Byzantium, where he seems to have passed the remainder of his days. He was a devout Christian, became *comes obsequii*, or lord high chamberlain, to the great Justinian—compiler of the "*Institutes*," "*Code*," and "*Digest*"—and was also body-physician to the same potentate. His "*Sixteen Books on Medicine*" was a kind of encyclopedia of the healing art as known and practised in his day. After Aëtius's time his sixteen "Books" were grouped into four "Tetrabilia," each of four "Sermones." A later name of the work was, in consequence of this arrangement, "*Tetrabiblon*."

Though Aëtius is, in general, a scientific writer, sometimes he abandons the strictly scientific viewpoint, and, when he does so, exhibits somewhat typically the spirit of his age. Thus, when making salves, one ought continually to repeat this incantation: "The God of Abraham, the God of Isaac, the God of Jacob, give virtue to this medicament." It should be observed that this was not a prayer at all, but that some especial virtue was supposed to reside in the particular words employed, and in their particular arrangement. It was, in other words, magic. When a bone has stuck in the patient's throat, the physician should seize him by the neck, and cry in a voice of loud command: "As Jesus drew Lazarus from the grave, and Jonah out of the whale, thus Blasius, the martyr and servant of God, commands, 'Bone, go up or down.'"

So both the religion and the science of Aëtius of Amida were sadly mixed with superstition. However, he was, to a great extent, a follower of Hippocrates.

Much of the "*Tetrabiblon*" is, in fact, mere compilation from the earlier Greeks—Archigenes, Aspasia, Leonides, Philagrius, Soranus, *et al.* Then, in addition, there is some original matter, part of which, at least, is of high value. Moreover, Aëtius has preserved the doctrines of many an ancient ophthalmologue, who, but for this mediaeval amber, would never have remained in view till the 20th century. Neuburger declares the ophthalmic portion of the "*Tetrabiblon*" to be "the best and most exhaustive" of antiquity.

In the case of such a writing, wherein, through the compass of a very few pages, the whole ophthalmic materia medica, therapeutics, pathology, prognosis, and even the most of the ophthalmic surgery of ancient times is presented in a clear and consecutive manner, the best procedure conceivable is not to talk about the book at all, but to show the work itself—to have recourse to autoptic proference, as our legal

friends would call it.[59] Here, then, is the book itself, as well as the present writer can render it in English.[60]

THE OPHTHALMOLOGY OF AËTIUS OF AMIDA.

"Chap. I.—*On the Structure of the Eyes.* [Omitted, because scanty, inadequate even for its length, and nowise to be compared with the ocular anatomy and physiology of Galen, already presented without abbreviation in this article.]

"Chap. II.—*On the Number and Kind of Diseases of Each and Every Portion of the Eye.* The so-called ophthalmias proper, as well as chemoses, taraxes, edemata, hypesphagmata and pterygia are diseases of the conjunctiva (epipephykos). This structure also ulcerates, and is attacked by carbuncle and cancer. But sclerophthalmia and xerophthalmia are affections common to the eye and to the lids. On the external surface of the lids arise water-blisters, meliccrides, and steatomata; on the internal surface occur roughnesses, together with their sequelæ, trachoma and the fig-disease, also chalazia, lithiasis, symphysis [our symblepharon] and mysis [our atresia]. And lagophthalmoi [literally, hare-eyes] are called those eyes in which the upper lid is drawn aloft, so that the organ cannot be covered. Ectropia are those affections in which the lower lid stands everted. But also colobomata, excoriation and ulcers occur on the lids. On the borders of the lids, however, comes the so-called trichiasis and loss of the hairs, that is, the lashes. This disease is also called ptilosis. There further occur phtheiriasis, pityriasis, and crithe [hordeolum, or stye]. Then, too, the so-called milphosis is a disease of the lid-borders, the edges, in this affection, being red, like red ochre. The angles of the lids are the parts affected in aegilops [lachrymal abscess]; but not these alone. Encanthis and caruncular atrophy are diseases of the canthi only. On the cornea occur foggy and cloudy spots, tiny marginal ulcers, superficial ulcer, abscess, excavated ulcer, trough-like ulcer, rupture, proptosis [i. e., of the iris], onychia, pyosis [our hypopion], phlyctenules, anthrax, cancer. On the iris appear: prolapse, myiocephala [literally, fly-heads], staphylomata, nails. Further, enlargement of the pupil, diminution of the pupil, irregularity of the pupillary border, distortion of the pupil. Hypochyma [cataract] occurs precisely in the iridic aperture, that is in the so-called pupil. In addition, an increase in quantity or a thickening of the aqueous humor prevents sharp vision, and its diminution dries up the lens. Glaucosis is noth-

[59] The ophthalmology of Aëtius of Amida forms in fact a perfect complement to the optics and the anatomy and physiology of the eye, as presented by Galen (and quoted in full already herein), so that these two writings (that of Galen and that of Aëtius of Amida) when considered together, form, as it were, an almost absolutely complete ophthalmology of antiquity.

[60] Using the Hirschberg text (which departs a little from the original), also, from time to time; the excellent German translation of Professor Hirschberg. There has hitherto existed, so far as is known to the present writer, no sort or kind of English translation of any of the works of Aëtius of Amida, and even the original text is very difficult to come by.

ing else than a high degree of drying of the lens. Amaurosis is an obstruction of the optic nerve, so that those who suffer from it can see absolutely nothing whatever, although the pupil looks clear. Also injured in the optical apparatus, without any perceptible external alteration in the eyes, are the nyctalopic. A plain misfortune for the entire eye is the thrusting forward of the eyeball; it is, in other words, a prolapse of the eye, the organ projecting externally.

"We must begin with the therapy of the simpler and more superficial eye diseases.

"Chap. III.—*The Treatment of Conjunctival Irritation.* The conjunctival irritations of the eyes, which are caused by smoke, overheating, dust, or some similar injury, are easy to heal; the patient being advised first of all to avoid the irritating causes, as sun, smoke, or the like; next, to bathe the eyes, in the beginning with lukewarm fresh water, later with cold; also to avoid bright light, and to keep the eyes closed. For the disease ceases without the use of any kind of medicine, if only a proper way of living be adopted. In cases of overheating, the patient should drink abundantly; for, if deep sleep comes upon him, an inflammation of the eyes, which had been feared, may subside. Therefore, too, one should not avoid the bath, and should adhere to a very careful diet. If the disease continues, the patient must keep at rest, and anoint the lids with collyria of saffron or roses, especially with that of Nilus. Gum in the eyes and stickings together of the lids, which occur in the night, may be cleared away, preferably by greatly diluted vinegar, also by cold water merely, in the form of fomentations; likewise by the use of one of the dry remedies from the class of those which lacrymate, especially that prepared from saffron, which is called 'seizing.'

"Chap. IV.—*The Treatment of Superficial Inflammation of the Eyes—According to Galen.* If a superficial inflammation of the conjunctiva occurs, without much pain, then the astringent collyria must be employed, their strongly biting quality, however, having been moderated by the admixture of white of egg. In most cases, indeed, the white of egg, together with the so-called 'One-day Remedy,' is sufficient to cure the superficial, incipient conjunctival inflammation, when these are not accompanied by strong inflammation and much pain. And often this treatment lessens the inflammation to such a degree that the patient may indeed in the evening take a bath, and then, on the following day, receiving an inunction of the nard collyrium, find himself absolutely well. On the first employment of the nard collyrium one should mix with the remedy a small quantity of astringent substances, also on the second employment. To those collyria in which astringent substances preponderate, a good deal of egg-white should be added, very little of the ophthalmic remedy itself being employed; in the case of those in which maturating substances overpoise (as, for example, that made of nard) one should employ the ophthalmic remedy thicker. These patients should take sponge baths once or twice daily, if the pain is not great; if it is more severe, then as many as five times. Regard should be had, of course, to the good or bad tolerance of the bathing on the part of the eye that is being treated. For all eyes

which, by nature, have large veins filled with blood, also all blue eyes, bear not the astringent effect of the collyrium; hence the medicament, for such persons, should be used in a much more watery form.

"Chap. V.—*On Ocular Inflammation and Chemosis in Plethora.* When vascular engorgement is present throughout the body, and the ocular inflammation is, in addition, strong and accompanied by much pain, then the use of collyria is by no means sufficient. We require in such cases a manifold treatment, and it becomes necessary to resort to the best and greatest means of assistance, concerning which indeed Hippocrates makes mention, in his *Aphorisms*, with these words: 'Diseases of the eye are cured by the drinking of wine or the bath or fomentations, or purgative medicines or venesection.' He does not, however, advise that all these remedies be employed in the same case; but, in one case, venesection; in another, purgation; in a third, fomentation; in another the bath; while in still another, the drinking of wine. We will now begin with the bath.

"Chap. VI.—*On Baths.* The bath is to be considered in those cases in which there is edematous inflammation (the swelling, however, is spongy in its elevation, cool to the touch, and of a clear color); where, further, the affluent secretion is not acrid and not hot, and even the swelling on the eyeball itself is neither very red nor very strong. This affection occurs mostly in old age, generally in the winter time, and attacks for the most part fat-bodied women; in short, edematous inflammation of the eye attacks such persons as have a cool and slimy brain. If, now, all the signs are present, then one should advise the bath with confidence; for it brings to the patient such an amelioriation that he needs no longer any treatment. He should, however, remain longer in the atmosphere of the bath, and foment the eyes often with dry fomentation by means of well squeezed out sponges. Under this treatment the edema may plainly be seen to disappear in the warm air and at the same time the patients to be freed entirely from the disease. If anything remains to be desired with respect to a complete cure, the nard collyrium should be instilled before the patient steps into the bath. If the pain appears to be moderate, the remedy should be made thicker, of course after it has been warmed on the whetstone. The patient, when, as above-mentioned, he has bathed and left the bath, should have the fluid carefully dried from him with sponges, and then should have his lids anointed with the same collyrium, and, moreover, be careful lest some of it get into the eye, for that, as a rule, causes much injury. For this reason, those who are sweating should not receive the lid-salve; there occurs, in fact, a gush of fluid into the bath, and the collyrium, if it gets into the eye and causes a sharp sensation, is able to draw the matter toward itself into the eye, and to double the inflammation. If the disease described above continues longer, and the condition of the secretion changes for the cooler, then should be employed inunctions of the head during the bath and dusting-powder afterwards. For this purpose the simple remedies should be employed; if, however, the damaging cause continues, one should pass over to the compound, the composition of which is as follows: laurel grains, roasted natron dissolved in wine, marjoram,

burnt lees of wine, and the like. Of powders one should use those which are most frequently employed by women, as for example that made of lillies, parsley seed, cypress grains, and dry mulberries. The remedies employed should be neither two strongly heating nor too sharp, but pleasantly heating with an admixture of astringent effect. The compounding of this collyrium has already been described in the preceding Book. The soap should, then, be rubbed into the head, during the bath, the hairs being separated one from another, in order that the medicament may be communicated to the body; moreover, the patient should be had to keep his mouth closed in the bath, so that the warm air of the bath may be strongly drawn in through the nose, and accordingly transform the morbid matter, which lies at the base of the trouble, so much the more quickly. After the bath the hair should be dried and the powder, as mentioned, dusted on. Thus far, concerning baths; now we shall speak about wine drinking.

"Chap. VII.—*On the Use of Wine.* Wine thins and improves the thickened humor; and often, under certain circumstances, serves to set it afloat. The wine, however, should be yellow in color, of a thin consistency, not extremely old and not too crude. Wine should be given chiefly to such as are accustomed to it, and whose temperament is somewhat dry and decidedly cold; for there seems to be a relationship between bath and wine. Whenever the requirement is to evacuate and transform the humors, the bath should be employed, but when the need is to transform, nourish, liquefy, warm, and evacuate moderately, then the wine. The wine should be mixed with a moderate amount of warm water, and it should be stronger than after the customary mixing. The added water should be absolutely pure, without smoke, without smell, and strongly boiling, in order that it may be thinner, and so suffice for mixing with a greater quantity of wine. The cup in which it is offered should be rather broad, and the patient should try to keep his eyes open while drinking. In this way the obstruction is dissolved, and, if normal and healthy tears flow to the parts, the patient will be free from his pains. For, in that way, the lids are relaxed, and become more mobile, as well as more elevated, than before. One should, however, be careful that no predisposition to diseases of the head is present; for, in such patients, a stroke of apoplexy can easily be caused by the drinking of wine. However, for what is left of the eye affection local remedies should be employed; at first there should be instilled one that is mild and not irritating, in order to assuage completely any irritation which may chance to be left. And, when the eyes are in condition and freed from the inflammation, an astringent collyrium should be used, as for example the so-called Hermolaus and similar remedies, the so-called 'restraining' remedies. For, as long as redness and inflammation are present, contracting collyria are not permissible; if one, by means of astringment, locks in the remainder of the matter, he increases the pain.

"So much concerning the use of wine; now we have to speak of venesection.

"Chap. VIII.—*Phlebotomy.* The phlebotome should be resorted to, when none of the often-mentioned contraindications are present, for

excessive pain in the eyes, that is to say, for such patients as experience great tension in the eyes, much redness, resistance to pressure, inflammation, a strong, hot flow of tears, and chemosis at the margins of the cornea and in the conjunctiva, so that, by reason of the severe inflammation, the lids turn outward, and in consequence the eyes are hardly covered; moreover the conjunctiva appears greatly reddened, and is much swelled, and the entire body is puffed up with blood. One should, however, open by preference the upper vein in the elbow, the so-called shoulder-vein; and enlarge the incision, so that the thicker ingredients of the blood may be evacuated, and the fainting occur promptly, to the relief of the pain and the moderation of the inflammation. When the entire body has been thus evacuated, what is left of the disease should be combatted by local remedies and the other treatment. Among the collyria should be used those like the swan salve and the Libyan; instilling them always diluted with warm water. Fomentations, however, should by no means be employed, but only careful washing with sponges, which have been dipped in lukewarm water. Nourishment should be given that is non-irritating, easy to digest, good for the body, and diuretic; which is free from sharp, salty substances that thicken the humors and cause loss of appetite. If the inflammation recurs, the nard collyrium, diluted, should be instilled until complete recovery.

"So much for venesection; now we shall speak of catharsis.

"Chap. IX.—*On Catharsis.* When neither the time of life nor the time of year, nor, above all things, a weakness of the stomach or any other viscus, or any other kind of circumstance provides a considerable hindrance, then resort should be had to derivation by way of the intestine; that is, for cases in which the tears are thin and abundant, or salty, sharp or cold, and the entire body contains bad humors, and the head is full of secretion and the body is obstinately constipated, and in consequence of this a quantity of troublesome secretions collects, while the eyes are afflicted with great pain. For, by venesection, we diminish the superfluity of blood in the entire body, while the object of catharsis is to remedy the evil commixture of humors. But the nature of purgatives is not one and the same, but multifarious; for the material of which the remedy is composed must be altered to correspond to the preponderating and disturbing humor. When, that is to say, there is present obstinate constipation of the body, then the patient must receive aloes, rubbed up with cabbage-juice and made into pills. When, however, the watery slime is present in excess, then one should give the remedy composed of resin of wolf's milk, pepper, and rock salt. When, however, the gall preponderates, there should be given the bitter remedy composed of aloe, adding to the individual dose powdered scammony, two scruples or a little less, in proportion to the strength of the patient. If, however, it is the black bile which preponderates, then should be added to the dose seven scruples of dodder of thyme and three oboli of scammony. When, now, by means of the purgative an adequate evacuation has been secured, and when the eye-disease is simple and not the result of a wound, one should use the astringent collyria, as for example that of Hermolaus and the like; and, in fact, they should be employed as instillations. On the other

hand, in the case of an ocular wound, the milder remedies should be employed, for example the swan salve and the Libyan collyria. The bearing of the Hippocratic aphorism on the present indication has already been shown, that is to say that cases of most severe pain and inflammation should be handled energetically. As, however, in many cases, the great remedies, especially phlebotomy and catharsis, must be omitted; there remains to be considered what, in such cases, there is to do. Together with the relevant signs on the whole body, already mentioned, there are, of course, also certain special ones to be observed in the eyes themselves, which reveal the entire nature of the disease. The secretion and tears are visible, now viscous and thick, now thin and immediately streaming from the eyes; now salty and now sharp and biting; now hot, now again cold. If at the very beginning of the ocular inflammation, mucus appears, this is rather a sign that the product of the disease is still crude: such an ophthalmia is likely to be long continued. In such circumstances, there should be employed a mollifying therapy by means of mild collyria, used as instillations, and such other procedures as bring about maturation. For the astringent collyria, which generally have a cooling effect, produce a felting or thickening of the organs, and, as they lock up the pus, they produce the greatest inflammation and severe pain, sometimes even a rupture of the cornea, through the tension produced by the fluids on all sides, especially when redness and inflammation predominate, and when very much matter is within the eyes. Here also belong for the most part the collyria made of opium and gum acacia, for example that of Antoninus and that of Hermolaus, and the so-called 'pelaria' and similar ones. Some physicians, who have made too free a use of the Antoninus collyrium, have, besides increasing the pain, also damaged the vision; for, by immoderate cooling, they produced a necrosis of the parts.

"Chap. X.—*On Fomentation.* Fomentation must be freely used when, especially at the beginning, a very thick mucus appears in the eyes, in order to thin it. In such cases the baths must be absolutely avoided, sometimes wine also; and only a little food be given, and that such as purges and attenuates. When the stools are hard, a clyster should be given of a decoction of mangold roots and bran, with honey and salt; and rub the mouth with mulberry salve, for the evacuation of matter, or free it from slime by means of a gargle: for the most of the patients of this kind have sensitive cheek-bone muscles and difficulties in chewing. Then one should instil, as already mentioned, the simple collyria; and in case a disease with heat is present, he should employ the Libyan remedies, as, for example, one which has been tested by us for such conditions and which is described in the works of Heras.[61] This is also called by him 'The Ashen Gray Salve,' and it contains no flowers of zinc. From the works of Heras we now extract the description of the flowers of zinc, for these are scarce and often sophisticated.

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[61] Probably Heras of Cappadocia, who flourished about 30 B. C. and who wrote a work on pharmacology, no longer extant.

"Chap. XI.—*Testing the Flowers of Zinc.*[62] The most beautiful flowers of zinc are not white, but tending a little toward bluish. The best test: strewn on glowing coals, it produces a kind of golden fire. The so-called ashen gray remedy is to be employed for such opthalmias as have been produced by hot humors. If, however, one has this not at hand, one should use instead one of the other Libyan remedies or the swan salve; if, however, inflammation with a hot flow of tears is present, it is necessary to drop in the hekatontarxion, diluted, if the eye is not ulcerous. If inflammation preponderates, there should be added to the hekatontarxion one of the non-astringent collyria; if, on the other hand, discharge prevails, the hekatontarxion must be empleyed. without admixture, though diluted.

"Better than all other remedies, in cases where thick, tough mucus forms in the eyes, is the collyrium prepared from wine, which bears the inscription 'god-like,' instilled with the white of egg, so diluted that the white of the egg is just barely made yellowish by the collyrium; for it produces the quickest alteration for the better, without the use of any other remedy. But after the use of the collyrium, should the patient feel a sticking or biting or heat, the pure white of egg, warmed, should be instilled, for the tears, streaming down from the upper parts, collect on the border of the lid, and produce the deceptive sensation of a grain of sand. And many physicians, accepting the statement of their patients that a grain of sand is lying beneath the lid, evert the lid and wipe it with a sponge; and apparently they free the sufferer for the time being from his imaginary trouble, for a later time, however, they have caused him the greatest injury. For, inasmuch as they make the inner surface of the lid raw, they double the penetrating pains. It is, therefore, not permissible to trust entirely to the words of the sufferer. It is advisable, now, after the use of the collyrium to employ the fomentations more frequently; for dialysis will follow the stoppage of the tears. Thereupon there should be instilled merely warm white of egg; soon the patients will be freed from their sharp pains.

"ON THE WHITE OF EGG.

"The white of egg loosens up the pores, and by means of its stickiness easily evacuates the collected tears, shapes the pores, and dulls the sharpness of the fluids; it also alters the thinness of the fluids to their proper thickness; and, to express the matter briefly, whether penetrating pains are present or not, the instillation of egg-white by itself, after the employment of collyria, is of great use; for it removes the entire morbid corruption. The substance of the collyria, moreover, howsoever finely divided it may be, will, because of precipitation in the membranes and lids of the eye, bring with it a certain unevenness, and, as this is in contact with the eye, it is plainly injurious.

"Chap. XII.—*On the Instillation of Milk into Inflamed Eyes.* Many

[62] As Hirschberg well remarks, and the reader will perceive, this is not a true title for the chapter.

physicians, with the intention of dulling the pain or of diminishing the heat or sharpness, are accustomed to instilling milk instead of the white of egg. When so doing, however, they overlook the fact that they produce for the patient instead of a moderate amelioration a tedious disease. They do the same as those who anoint wounds, and so favor the production of proud flesh. Moreover, milk easily decomposes, transforming itself into acridity in the abnormally increased heat of the inflamed eye.

"So much concerning the hot inflammation of the eye. It is next in order to speak of the cold variety.

"Chap. XIII.—*On the Cold Disease of the Eye.* In the cold disease of the eye the pains are less than in the hot; the former, however, becomes more rooted in spite of the treatment, and, if inflammation sets in, there follow swelling and a leaden color. Generally, though, in this affection, the eye is not much irritated, nor is there great redness; a flow of tears occurring, however, at the lesser canthus, sometimes also at the greater, but of a slight quantity and of a cold character. In case the disease is of long duration, the lids inflame a little and sharp pains follow. The disease arises when slimy and cold secretion preponderates in the head, sometimes after exposure to cold air, especially after the bath. In these circumstances the intestines should be evacuated at the right time by a clyster, and then a bath given and wine, as was mentioned shortly above in the apophthegms of Hippocrates. At the beginning of the inflammation the nard collyrium of Zoïlus should be instilled, when it has been liquefied to a watery consistency, the consistency being increased, however, with the diminution of the epiphora. It is a good general rule in the treatment of all eye diseases: To increase the consistence of the local remedy, as the secretion diminishes. When, however, the inflammation in the eyes abates, the nard-remedy, liquefied in water, should be stroked beneath the lid with the head of a probe.

"Chap. XIV.—*On Emphysema—According to Demosthenes.* We speak of ocular emphysema when the eye, without plain cause, swells up, changes color, becomes somewhat inflamed, itches, and suffers from a flow of tears. This occurs mostly in advanced life, the itching commencing at the internal canthus, as if the patient had been stung by a fly or a gnat. The disease occurs frequently in summer. The treatment consists in fomentation with a sponge, the inner surface of the lid then being anointed with honey, either alone or mixed with saffron powder. Also the very useful eye-water of Erasistratus helps. Further, the outer surface also of the lids should be rubbed with honey. It is of service to evacuate the bowels, then to bathe, and to pour upon the head warm, mild water, and, after the bath, to administer wine. When, however, the itching is severe, and the age of the patient and other circumstances permit, and no other contraindication is present; then phlebotomy may be done at the bend of the elbow or derivative remedies be administered, after a preliminary evacuation of the bowels. Affusions of warm sea-water are valuable, especially in winter.

"Chap. XV.—*On Edema.* There is edema of the eyes when the lid is externally lifted up and changed in color, is heavy, movable with

difficulty, and looks pale. At times, too, the white of the eye lifts up for a short distance over the black [of the eye, i. e., the iris]. The swelling on the outer surface of the lid is spongy, as it yields promptly to pressure by the finger, but also fills again quickly. As a rule it is painless and has the same color as when normal; it generally arises from a watery fluxion. One should treat all edemas which only attack the lid externally without participation of the eye itself, after evacuation of the intestine by means of clysters, merely by lid-salves, after fomentation with a sponge. The spongy and even-colored edemas should (likewise after evacuation of the intestine and fomentation) be anointed with honey on the inner surface of the lid. Benefit is also received by these patients from instillations of the eye-water of Erasistratus. Further, they should be advised to use gargles of cooked honey, raisins, thyme and pennyroyal, while avoiding the sharper remedies, like wild grapes. In cases where the eye has suffered together with the lid, one must first empty the bowel, keep the patient fasting, and use sponge fomentations. At times douching of the face is to be used by way of preliminary, especially when itching is present. Further, one should rub in externally wormwood powder or hyssop with honey. When, however, the entire body is sick, one should boil lentils, press them through a cooking sieve, or an ordinary sieve, or a thin cloth, mix with honey what is squeezed out, and employ as an ointment. At the time of the summer heat, however, one should anoint with saffron and honey of wine, or with the juice of hypericon, or of nightshade, or of endive. Celandine is also effective. The eye itself should be rubbed with the eye-water of Erasistratus, or with some other which is able to extract from the eye much moisture.

"Chap. XVI.—*On the Hard Swelling (Edema).* There also appears on the eye a hard swelling which generally offers resistance to pressure, is hard to the touch and extends to the cheeks and the eyebrows. This arises mostly from carbuncles and tedious ocular inflammations, which are especially common in women. When the lids are thickened inwardly as well as outwardly, they should be averted and, as usual, the collyria for trachoma rubbed in. When, however, the disease is confined to the external surface of the lids, the eye should not by any means be anointed, but the entire body and the hardened parts should be massaged. Then the eyes, being closed, should be massaged for a long time, after which the following collyrium may be employed: Lid-ointment—frankincense, 6 drachms; gum, 6 drachms; fibrous alum, 1 drachm; pomegranate peel, 1 drachm. The powder should be rubbed up with water and allowed to dry. Of evenings, however, a piece of soft linen and wool should be bound upon it; if the patients bear it well, also in the daytime. They must, however, take plenty of gentle walking exercise. Baths, on the other hand, should be avoided, the sun and all kinds of heat, beans, dainties, excitement, violent breathing, vomiting, and coitus.

"Chap. XVII.—*The Common Treatment of Ocular Ulcers—According to Severus.* The eye ulcerates, in certain cases, when, from without, something gets into it; in others, by the flowing in of humors or by erosion, whether of the conjunctiva or cornea, the lid or the canthus.

The common treatment of all ulcers which occur upon the eye, in whatsoever way they may have arisen, is the following: First of all, attention should be given to the whole body, so that whatever is excessive in the constitution may be done away with by venesection, purgatives or clysters. When, however, the condition requires all these, all must be employed. The manner of life must be arranged in opposition to the disturbing forces—by thickening thin secretion, thinning the thick, dividing the tough, mollifying the corrupt and acrid, and, in general, restoring to the patient the natural commixture of humors. The body must be kept liquid, and massage appropriately applied to the lower extremities; further, frequent gentle walking exercise should be prescribed and the drinking of water, but only an occasional bath. Of collyria only the milder are to be instilled in the ulcerous eye, as, for example, the "Star," most famous of all remedies against ulcers, and the white salves, which are called swan salves from their color, especially those prepared from goatshorn. But when the ulcer is coated, the collyrium should be liquefied with goatshorn juice before the instillation; for its quality of toughness renders easy the removal of the coat. It possesses. moreover, in addition to its toughness a certain relaxing power, so that, frequently, in the treatment of ulcers, we have accomplished all that was necessary by means of the use of goatshorn. When, however, the coating is considerable, then it is necessary to add to the goatshorn a little honey.

"PREPARATION OF GOATSHORN JUICE.

"The goatshorn plant should be cleaned most carefully, very often rinsed and softened with sweet, pure water in an earthen, well-burned vessel, a brazen vessel being avoided for the decoction. On the next day the water should be poured off, pure water again added, and the whole boiled over a slow, smokeless fire. The first and second decoction should be thrown away, with the object of getting rid of harsh matters. Then absolutely pure water should again be added, the vessel covered, and the liquid boiled until it reaches the consistency of a rather liquid honey. Then it should be strained through a piece of linen, without squeezing out any of the goatshorn plant, but only the juice which comes away of itself. This should be used as previously mentioned. The decoction may be kept for use only to the second, at most until the third day, for it becomes too acrid if it stands any longer. When, however, the ulcers become clean, the goatshorn juice must be no longer used; and, if the ulcers are still deep, the Libyan collyrium must be employed, or, better, that of frankincense. When, however, the ulcers are filled, become level or just a little hollow, those collyria must be employed which promote cicatrization, such as that of Cleon. On the common treatment of ulcers enough has been said; now I must speak of the way in which each individual disease must be combatted—and first of those ulcers produced by the entrance of injurious substances from without.

"Chap. XVIII.—*On the Falling Into the Eye of Insects, Husks, and Grains of Sand—From Demosthenes.* When a gnat or other insect

gets into the eye, the sound eye should be closed, and the painful one opened; then the insect will come from the eye of itself. When, however, a husk, grain of sand or something of that kind gets in, one should try again to do the same thing. If the object still remains in the eye, it should be removed with the finger, or by pouring in water, milk, or, best of all, honey water, repeatedly. If it clings still tighter to the eye, then it should be drawn out by one of those remedies which, having the consistency of plaster, still are not acrid—for example, that made of honey.

"Chap. XIX.—*On the Entrance of Unslacked Lime Into the Eye.* If unslacked lime enters the eye, and water or milk is dropped in, then the lime draws to itself the moisture and burns out the eye. The corrosive quality of the lime is weakened by the pouring in of egg-white and, still more, by the oil of roses.

"Chap. XX.—*On Ulcers Following Burns.* All ulcers following burns produce hard eschars; for which reason they must be continually moistened by the instillation of milk and white of egg. Of collyria, use those containing antimony and those of Cleon.

"Chap. XXI.—*On Foreign Bodies Wedged into the Eye.* If a splinter or a fish-bone becomes imbedded in the eye, it should be removed by means of a pincette, taking care to pull in a straight direction, lest the foreign body be broken off. If the substance does not project but lies on a level with the tissues, take two sounds and press with their heads against the eyeball in such a way that the foreign body stands between them. As soon as it peeps forth, it should be extracted with the pincette. Then should be instilled the blood of the turtle-dove, or of the common dove, or white of egg. When the foreign body cannot be removed at once, the eye must be instilled and receive poultices together with remedies against inflammation; for, after several days, when the puncture has begun to suppurate, the implanted body will come out spontaneously.

"Chap. XXII.—*On Hyposphagma.* It is called hyposphagma when, in consequence of a blow, the vessels in the ocular membranes are torn or contused and blood runs under the conjunctiva, the color of the eye at once becoming that of blood, a little later blackish blue. These cases must be treated (in addition to the above-mentioned help from the general therapy of ulcers) by venesection and purgation, together with what is incidental to these, and by the instillation of lukewarm white of egg or the blood of a turtle-dove or of a common dove. Externally there should be applied wool soaked in wine, oil of roses, and the white of egg, and held in position by a bandage. On the following day frequent fomentations of the eye should be made by means of sponges and a decoction of wormwood, or, still better, hyssop, and wool applied externally. But when the eye has become free from inflammation, honey, or the eye-water of Erasistratus, or the sweet-smelling collyrium, should be employed. Of excellent effect is also the instillation of nightshade juice with honey and fumigations of incense and asphalt in equal parts. For hyposphagmata of long duration the following acts well: Into a copper vessel pour the urine of an innocent boy and beat it with a brazen pestle in the sun for a number of days, until it

gives off sufficient moisture, and, after it has been well dried up, dissolve it, mix it with honey, and employ the mixture. Apollonius of Memphis, recommends the following for hyposphagmata and contusions: bloodstone, ass's blood drawn from the heart; in equal parts, dried in the sun. This should be rubbed up with the urine of an innocent boy, added to the juice of Iberian cress, rubbed up well, and instilled. Or the same kinds of collyria may, when being used, be mingled with salt water. Another of the same kind is the following: 4 drachms of bloodstone, 4 drachms of dried dove's blood, 4 drachms of ass's blood, 2 drachms of gum. Rub well together, as mentioned above, and use.

"Chap. XXIII.—*On Punctured Wounds of the Eye.* All punctured wounds of the eye, produced by the writing style or similar instruments, should be treated (after the use of the general cure above mentioned) by the instillation of the blood of a turtle-dove or ordinary dove or of egg-white, immediately at the beginning of the trouble. At the outset, fomentations and warm poultices should be avoided; after the third or fourth day, however, after the evacuation of the entire body, foment with sponges and apply poultices, together with the remedies against inflammation, yet to be described. Collyria should be employed which irritate as little as possible, even when the ulcers appear unclean; therefore to be used are the remedy from metal ashes, the ash collyrium, the star remedy, and the like. The rose collyrium of Nilus is also effective, diluted with white of egg before its use.

"Chap. XXIV.—*On the Deeper Injuries.* When, however, a deeper and larger wound has been inflicted on the eye, so that there is danger that the eye may run out; then one has to be careful that severe inflammation does not arise and fever after it. First of all should be employed venesection at the bend of the elbow, at least when the strength of the body is sufficient to permit of it; for we have no better remedy at the beginning of the trouble. If, however, we have to wait before phlebotomizing, then a proper purgative should be given, or at least the body should be evacuated by derivative clysters. Into the eye should be instilled the white of egg, and poultices should be applied of egg-yolks beaten up together and mingled with oil of roses and wine. All this should be poured into a vessel, slowly warmed, and soaked up in wool. On the following days one should practise fomentations with a decoction of roses or melilot, and instil woman's milk with egg, warm. Of poultices should be employed those described for inflammation, especially that of poppy-heads, melilot, saffron, and bread. There should also be rubbed in a little opium with much saffron on the forehead and temples. The poultices should be light and applied to the upper lid only, so that the patient may open his eyes and remove the excess of tears. The ocular bandage, too, must be light. If some of the patients cannot bear poultices, they must be anointed on the lids, on the temples, and on the forehead with the rose remedy of Nilus. But if the pains become too severe, then the hair of the head should be shorn, a cupping glass applied to the neck and the vertex, and one of the pain relieving remedies administered for the night. About the fourth or seventh day, however, the rose-remedy of Nilus, well diluted,

should be instilled until the eyes are well. All food should be given half liquid, very nutritious, and easily digestible; for the bowels must always be kept open. The use of wine must be forbidden till the inflammation has gone down, and, in addition, everything avoided which makes the head full and produces secretion.

"Chap. XXV.—*On the Escape of the Egg-like [Aqueous] Humor.* When, after a punctured wound of the eye, the aqueous escapes, so that the eye, to a certain extent, collapses, then, as described, that must be done which is preventive of inflammation. When, however, the inflammation and the formation of ulcers is over, then a bath is useful, and thin wine, in moderate quantity and nutritious, in order to restore the fluid properly and to cause it to accumulate.

"Chap. XXVI.—*On Proptosis of the Eye.* Proptosis of the entire eye occurs in consequence of a violent injury to the head, or of anthrax ulcers, or when the deeper vessels and membranes to which the eye is adherent, tear off or become slack. In some cases, the entire eye falls out so that it cannot any longer be covered by the lids. Sometimes it falls even as far as the cheeks or the eyebrows. This follows chiefly falls from a height, or violent blows on the head. The condition is dangerous. Venesection or purgation should be resorted to at once, and the other measures should be instituted which have already been described under the general treatment of ulcers, and the diet should be restricted. Wool should be moistened in beaten up eggs, rose-oil, and wine, and then applied. Then poultices should be used of melilot, poppy-heads, and henbane leaves, with bread or fleabane, which have been soaking but a short time. And the poultices should be continually changed, in order that the parts may not become warm, and pass into suppuration. On the days following, when the inflammation goes down, a cupping-glass should be applied to the occiput, with scarification; but so long as the inflammation continues, the cupping-glasses are not proper. Always to be instilled are lukewarm white of egg and milk. When the inflammation ceases, the rose-remedy of Nilus should be used, alone or combined with smokeless honey, in order that the corrupt humors may be eliminated. At the same time, however, the head of a sound should be passed beneath the lid, so that no adhesion may take place. If, now, the prolapse is very decided, and no hope exists of restoration of the sight, then should be employed such poultices as promote complete suppuration, such as those of wheat-flour, and lentils with honey make a good poultice. When, however, the inflammation yields, the patient is to be given a bath.

"Chap. XXVII.—*On Superficial Ulcers Produced by the Access of Fluids: that is, on Cloud, Mist, Superficial Burning and Deep Burning.* Those superficial ulcers which arise from the afflux of fluids, have a varied designation. The 'mist' is a superficial ulcerous formation over the dark part of the eye, by virtue of its dark blue color resembling misty air. It covers a large portion of the dark part of the eye. When it lies in front of the pupil, the vision is obscured. 'Cloud' is the name of such an ulcer of the dark part as is deeper, smaller, and whiter in color than the fog. We speak of 'superficial burning' when the dark of the eye has become raw and appears to have been slightly burnt,

being of an ash-gray color. A 'deep burning' is an ulcer which mostly occurs after fever, with an unclean slough, and either on the black or the white. On the black it goes into the depths, and, inasmuch as during the purification of the ulcer, a breach of the tunic occurs, the fluid of the eye slowly escapes through the ulcer, and so the whole eye runs out. These most superficial ulcers, whether arising with or without fever, should be treated in the following manner: First, evacuate the bowel by means of a clyster, then anoint with the diluted rose-remedy of Nilus, instilling milk in the intervals between the employment of the collyrium. Gradually, as the days go by, the Chian remedy of Apollonius or that which is called 'fragrant' should be added to the collyrium of Nilus. Later, this remedy may be used unmixed, for it produces rapid cicatrization, and scars which are so delicate as to be almost invisible.

"Chap. XXVIII.—*On the Phlyctenule.* The phlyctenule is a small ulcer which arises at the circumference of the iris [i. e., cornea] including on the one side a part of the white, on the other a part of the dark, and which has a pale color. When it is deeper and, at the corneal margin, has a coat, and has also purified too rapidly, the iris may sometimes prolapse. Therefore, in the beginning of the affection, one should employ obstructing remedies, so that the ulcers may be freed of inflammation, the cornea thicken a little, and the eschar be cast off.

"Chap. XXIX.—*On Pit-Ulcers and Hollow Ulcers.* We speak of 'pit-ulcers' when, over the dark of the eye, appear ulcers which are excavated, narrow and clean, similar to punctured wounds. 'Hollow ulcers' are round and broader than the pit ulcers and less deep. One should not seek to cleanse them by means of acrid remedies, but, instead, try to fill them out by milder ones, especially the so-called pit-ulcers. Hollow ulcers, however, if chronic, should be treated at first with slowly purifying medicines, and then pass over to those which fill up, for example those of frankincense. When they are already level or just a trifle hollow, the remedy of Cleon should be employed, and, if there is much filthy coating, honey-mead should be dropped in. I, however, have added honey to the decoction of goats-horn plant (which had been prepared in accordance with the foregoing description) and so attained the object more quickly. I use for hollow and unclean ulcers the Theodotian collyrium of Severus, diluted with egg-white. It not only purifies the ulcer painlessly, but also, in the quickest way, brings it to cicatrization. Always there should be remembered in this connection the above described treatment of ulcers in general.

"Chap. XXX.—*On Suppuration, or Onychia.* Suppurating ulcers have received a varied designation. Onychia is that condition in which, from a deep ulcer, the pus flows down, sinks between the tunics of the eye, adjusts itself to the periphery of the iris, and so produces the appearance of a segment of the finger nail. When more pus is present, so as to cover half the dark part of the eye, or even shines through the entire extent of the cornea; then we say that the eye is festering inwardly. These conditions also arise, however, without the formation of ulcers, that is, when headache has preceded or some ex-

ternal ocular inflammation; there is also a violent internal inflammation of the eye, when, because of the abundant accumulation of exudation, some of the vessels of the iris burst and the blood which issues from them suppurates. There follows, however, as a rule, upon the formation of hypopion violent pulsating pain, a reddening round the whole eye, and pains in the temple.

"In the treatment of these cases, fomentations should at first be avoided, and the bowel be emptied by a clyster. Then the upper elbow vein should be opened, and later the vein at the angle of the temple, but without the customary ligature about the neck. A cupping-glass, too, should be applied to the occiput and leeches to the temple. Then should be instilled the collyria for inflammation, especially the rose remedy of Nilus, diluted with the white of egg or with milk. After the third day, fomentations should be made by means of sponges, at first in a moderate way, afterwards more freely. One should leave aside all oppilating collyria and use the quieting and dispersive, especially the Chian remedy of Apollonius and similar ones, which, prepared from myrrh, are, for that reason, known as myrrh collyria. The strongly dispersive and drying remedies produce at once a sufficient removal of the watery constituent of the pus, but make the remaining portion more solid and dry it into an insoluble mass.

"From Galen's Treatise on Therapy: 'A very experienced oculist of our day has cured patients of hypopion by shaking their heads. He set them, that is to say, upright on a chair and grasping the head in both hands, shook it so thoroughly that we plainly saw how the pus sank down and then remained below, obviously because of its weight.'

"When, now, the pus is superficial and sticks to the ulcer, the pus, as a rule, evaporates completely, as the ulcer becomes clean. When indeed the ulcer is superficial and lies more above, while much of the pus lies deep and considerably lower than the ulcer and is not removed by medicines, the eye must be opened below the pus, the needle being introduced obliquely at the corneal margin (the so-called 'garland') and the pus afterwards evacuated. This operation, however, may be undertaken only when the parts are free from inflammation.

"Abscesses of the conjunctiva over the white of the eye should be divided by the lancet from beneath, making under the conjunctiva a slow, scissors-like motion.

"After the evacuation of the pus, in both these classes of cases, egg-white should be instilled. Then an entire egg should be beaten up with honey of wine, a little sopped up in soft wool, and laid upon the eye, and there secured by a bandage. On the following day, foment with sponge and warm water, instil the white of egg and apply again the above-described compresses. Three days later the collyrium named for Dion should be rubbed in, or one of those which are used after the operation for hypochyma [cataract]. The remedy of Dion consists of the following ingredients: Of metallic ashes, 3 drachms; of frankincense, hammerings,[63] myrrh, acacia, spikenard, and opium, each 1

[63] The particles of metal which fly from between hammer and anvil.

drachm; of gum 6 drachms; rainwater. It should be instilled with white of egg and followed by the compresses mentioned above. If, however, after the abatement of the inflammation, granulations peer out from the perforation wound, then the collyrium above-mentioned should be dissolved and used as an ointment with milk. The Chian remedy of Apollonius also evens beautifully, and purifies besides.

"Chap. XXXI.—*On Pustules.* Pustules arise indeed not only on the white of the eye but also on the lids, and generally on the cornea. A few of the corneal variety form on the surface, others in the depths. For the cornea consists to a certain extent of four layers, which are very dense and solid. Sometimes it happens that the pustule forms beneath the most superficial layer: then it too exhibits a darkish color. Again, however, the pustule lies beneath the second or third layer; then the color of the vesicle is whitish, because the disease lies hidden in the depth of the cornea. For the natural color of the vesicle is black. On the contrary, the cornea is white and very similar to plates of horn. Now, the more the vesicle hides within the depths of the cornea, the more it exhibits the color of that membrane, and, at the same time, the more painful and serious it becomes. For whether the pustule bursts because of the accumulation of fluid, or whether it is corroded by that fluid's acridity, and so an ulcer is formed in the cornea—always the superficial ulceration is the easiest to heal, while the deep variety is difficult. For danger is always present that the remainder of the cornea at the ulcer's bottom, (inasmuch as this is very thin) may rupture, and a prolapse follow of the iris and the ocular fluids: especially when the rupture occurs in the pupillary area. And a further bad result may happen in the pupillary area, even when the disease is treated skilfully: that is, after cicatrization the patient will not see, because of the scars which have formed. As, however, sometimes, together with the destruction of the cornea there is prolapse of the iris and the production of a condition resembling a superficial pustule, it is highly advisable to discriminate these two conditions accurately the one from the other. The superficial pustule, then, is black throughout its whole extent, but not saturatedly black. In prolapse of the iris, however, the prolapsed part may, according to circumstances, be black or blue; but (the most important sign) the circular base-line surrounding the prolapse will be found to be white. For the hue of the cornea is white, after the iris has prolapsed through its rupture. Then, too, the size of the pupil is now and then diminished in prolapse of the iris or its shape is changed absolutely. For the pupil, in iris-prolapse, is not able to preserve its circular form exactly, but must, in part, appear as if distorted. Consequently, one has to notice the symptoms mentioned, and distinguish between these conditions for the treatment also must occasionally be changed to correspond to the differences in the diseases. In prolapse of the iris we employ the more astringent and corrosive remedies, but in pustules the slowly dispersive.

"Pustules should be treated, at first, by the avoidance of much talking, sneezing, excitement, holding of the breath, and brilliant light. Then, too, the drink and food should be restricted as much as possible,

and the bowels emptied with a sharp clyster. One should also seek, by the administration of an abundance of milk, to keep the bowels liquid in those patients in whom the milk neither sours nor produces hot belching or vomiting. In such cases, milk is to be avoided, while, on the other hand, a laxative effect is to be secured by chicken-broth or the juice of the zaffer-thistle or by aloes, or by any other gentle remedy. The more violent purgatives are to be avoided, especially those which digest badly. For such patients, too, we avoid bandages and the many kinds of compresses, for they are very injurious; and that, too, not only in these cases, but also in every case of ocular inflammation proceeding from acridity of the humors. Poultices, however, should be applied, especially in the beginning, when, at the same time, a stronger ocular inflammation exists—and these should be light and flat. The poultice should be laid on thin, soft pieces of linen, and these applied to the entire eye, including the brow, cheek and temple.

"They should be allowed to remain as long as they are moist, but, when dry, they should be removed and replaced by others. Of use are also the remedies for more violent ocular inflammations; as the yolk of soft eggs, pulverized with saffron and a little opium and a moderate quantity of sweet wine with bread. The astringent remedies are also proper, such as boiled quinces or pomegranate-peelings seethed in water. One should refrain, as stated, from bandaging the eyes of these patients, for it is very injurious. When, however, the inflammation has moderated, one should also lay aside the poultices, because of their weight. A fitting collyrium, at the outset, is that of Nilus, made from roses, diluted with milk and instilled. If the treatment is successful, the collyria made of myrrh, and of frankincense, and of saffron should be employed. Somewhat later, the collyrium from nard is applicable. Externally the lids should be rubbed with the rose remedy of Nilus; the forehead, however, with gum acacia and cytinus hypocistis together with saffron and a little opium. Fomentations, at the beginning, should be added, of a lukewarm character, for, at the beginning, those which are hot make the inflammation worse; later, however, the warmth should be increased. Promenades and other exercises are injurious in the beginning: baths and the other procedures which produce sweating, even after the beginning. Wine should be abstained from during the entire period of treatment. On the contrary, warm water should be used as a drink, and nourishment should be taken which is easy to digest. Entirely to be avoided, in these cases, is phlebotomy from the forehead or from the corners of the eyes; for after such venesections, prolapse of the eyeball occurs, especially when there is violent inflammation or deep ulceration.

"Chap. XXXII.—*On Carbuncle of the Lids—According to Severus.* As carbuncles, too, belong to the species of pustules, and also form occasionally on the lids, bringing the eye into violent sympathy with them: therefore I will mention also certain moderately helpful measures for these affections, first, however, explaining their diagnosis. Many other kinds of abscesses look to the inexperienced like carbuncles. For styes and nodules and comedos arise on the lids. But these are generally accompanied by a certain amount of swelling, and are usually

free from inflammation and are not harmful. Carbuncles, on the other hand, exhibit from the very beginning an inflammatory reddening, so that, to the patient, the eye seems to be burning up. But the swelling and elevation are not produced so quickly. For, on account of the excessive heat, the structure of the carbuncle undergoes, to an extent, a kind of bursting open. And the secretion which is of an acrid, corrosive nature, is dried by the upper surface of the carbuncle into a covering crust, which disseminates the disease to the surrounding parts. There follows a violent inflammation not only of the eyeball but also of the neighboring parts, especially of the glands at the ears, so that carbuncles cause even extensive ulceration and rupture of the eye, together with prolapse and madarosis. The scars of the carbuncles become thick and fester continuously. In the rest of the body is found blood which has flowed from the carbuncles, and which is black in color because of the excessive heating. But, in the eye, no blood whatever is carried away from the carbuncles, because, in the eye, no excess of blood at all is present. For this reason, too, most of the carbuncles on the lids are white. If, because of proper treatment, liberation from the disease follows promptly, the carbuncle becomes invisible. When, however, it persists longer and does not readily permit of dissipation, then the site thereof must of necessity take on a blackish discoloration.

"One should not, at the commencement of a carbuncle, resort incontinently to poultice and inunction, but first of all evacuate the bowels by means of a clyster; then produce derivation by moderately boiled milk; and, of course, in plethoric patients, phlebotomize. Then, after sponge-fomentations, the simple ophthalmic remedies should be employed. For, by the use of astringent and cooling medicine (often, too, those of the drying class) these patients are made well. At the beginning, so long as the overheating continues, we seek to refrigerate the heated humors. We pulverize coriander, and rub it on the reddened part of the lids. Nightshade, too, rubbed up with sweet wine, and laid on the carbuncle, has at times produced a rapid disappearance of the disease. This treatment proves of very great use in the beginning. But the cooling poultices, which, in carbuncles, are laid upon the eye, hinder decidedly the afflux to the carbuncle, and alleviate the external inflammations. There then arises, however, the fear that the afflux [of the humors] may attack the eye itself. For this the nightshade has been responsible: applied with sweet wine, it has overcome the swelling immediately, but caused the eye to become fuller.

"Carbuncles which have already eaten widely must be cured in various ways. That which flows away from them is acrid and biting, so that the disease even consumes the neighboring parts; and danger exists of damage to the eyeball itself. For, in such patients, it is generally eroded. It is then necessary to dry up the eye with a sponge, and to apply to the eye gentle affusions with a decoction of roses or blackberries or vine-tendrils. But the decoction should be lukewarm, or, rather, like cow-warm milk.

"When, however, the place has a moss-like appearance, because the corrosion has taken the upper hand (often, indeed, the lid falls away because of these secretions) we add also the juice of cytinus hypocistis

to the water and take myrrh-berries and gum acacia in sweet wine, and rub the parts with these. The medicaments should be chosen with regard to the part of the body that is under treatment, here those of moderately strong action. For the part absolutely does not bear the more strongly acting remedies, such as verdigris. That is to say, through their corrosive action all hope of saving the eye, which may yet be present, is lost. For the tendinous and denuded parts are damaged by the strongly burning and corrosive medicaments, so that these may even produce gangrene. Therefore take the peelings of pomegranates, especially sour ones, boil them with bean flour, shave away the pulp which still clings to them, and pulverize them with a little honey. With this application we have given patients great benefit. For it rapidly produces a cure, and hinders, to a certain extent, the afflux to the eye. Salves increase the corrosion.

"When, however, the surrounding corrosion continues to increase, then the pomgranate peels should be boiled in wine and applied by themselves, without the bean flour. But the gangrenous tissues can better be removed by pomegranate peels, which, boiled and finely divided, are laid on with honey.

"There are also compound remedies, which are very good for carbuncle. For at the outset of the heating the trochee of nightshade generally works wonders: it cools and dries in fitting fashion. When, however, it is necessary to astringe proud flesh, we apply the dry trochees of Musa in powdered form. When the necessity is present of producing flesh, we likewise dissolve Musa's trochee, and rub it on with must which has been boiled down thick. If the indication is for cicatrization, then again we employ the trochee of nightshade.

"Apollonius, however, says that for carbuncles on the eye the following should be employed: metallic ashes, 4 drachms; fibrous hematite, 2 drachms; saffron, 3 oboli; slightly roasted myrrh, 3 oboli. Rub it up with odorous pine until it is dry. Add of sweet Cretan wine, or of some other which, likewise, is not harsh, one glass, and take it up while it is being rubbed together, and anoint with it. For it removes the scabs and purifies the ulcers, not only when the disease is seated on the outer surface of the lids, but also when it exists in the depths. It is also of use for discharge and phlegmon.

"But, when pain attacks the eyeball itself, then rub in the following collyrium, which bars at once all further corrosion: dross of lead, which has been powdered, washed and dried, 4 drachms; spikenard, 1 drachm; gum, 2 drachms; the juice of 120 olive-tree-leaves; with one glass of water which you add to the leaves, press the juice out, filter it, and rub up, and so apply it. The rose remedy of Nilus is also effective, rubbed up with white of egg, and better still the nard remedy of Candidus, rubbed under the lid until the disease has entirely disappeared. One must, that is to say, when the ulcers have become clean, rub it in (after preliminary fomentation) under the lids with the head of a sound which has been dipped in milk. The corners of the lids, too, should be drawn apart, that no stiffening or adhesion may appear. For the same reason the eye should not be bandaged, especially after the ulcers have become clean.

"In the beginning, when the strongest inflammation and tension exist, we are obliged to use poultices made of boiled bean-flour and bread. A poultice of fleabane also reduces the inflammation; for, even in the most severe pains of the other ocular inflammations, it brings sleep to the patients. But the poultices must be very light. Also, poulticing must not be too long continued, for it increases the corruption and damages the eye decidedly, as I have already mentioned when speaking of pustules. As soon, therefore, as we have modified the inflammation to a certain extent, we abstain from poultices the same as in the case of pustules.

"Chap. XXXIII.—*On Cancerous Ulcers of the Eyes—According to Demosthenes.* Ulcers which form over the colored portion of the eyes, which do not cicatrize, and which are small, painful, and furnished with blood-vessels—when these become hard, they are said to be cancerous. Sometimes, when they seem to cicatrize, they crumble again without obvious cause. Deep, stabbing pains are felt as far as the temples. There ensues, in these cases, a discharge of thin and moderately acrid secretion. The white of the eye, and even the black too, is always red. The patients are absolutely without appetite. Their pains are decidedly increased when acrid ointments are employed. The affection attacks by preference old men, in the course of long-continued ophthalmias, and women who are not experiencing the monthly purification.

"One should treat the affection with care for the whole body and also with the prediction that it does not permit of a complete cure. But it can be ameliorated, first by a fitting way of life, and then by remedies which are able to lighten the pains. The way of life should be governed in this manner. On arising, the patient should massage his entire body thoroughly with sweet oil, the head, however, with a little oil of roses or juice of the husk of grapes; then hang a green flap before the diseased eye, and promenade in a shady, windless place, without talking and without other exertion, and, so far as possible without shaking the head; and so take a long and restful walk. Then he should betake himself to a dark room, with very little lamplight in it, and, with the aid of another person, anoint the body (with the exception of the head), especially the hips and lower extremities, and then drink perhaps one glass of moderately boiled skimmed milk. For this dulls the acrid humors and opens the bowels. If, however, the patient cannot bear milk, then fine barley meal should be strewn on sweet wine, appropriately thinned with warm water, and this should be given to him to drink. Later, however, when he is hungry, he should content himself with two soft eggs, and, further, omit all sleep in the daytime. About two o'clock, however, after an innunction, he should take pure bread, with a side-dish of some slimy substance, for example soft eggs, sucking-pig twice boiled in water; of fishes, however, muraena, roach, whiting; vegetables, mallow, spinach, lettuce. Peeled spelt, however, may be added, with rice and pot-herbs, boiled in chicken-broth and swine's feet, and ankle bones, thoroughly boiled. All should be in moderate quantity. Wine should be given, white and thin, slightly sour; this too in moderate quantity. Things pickled in

salt and leguminous plants should be entirely abstained from, and even the bath, when necessity does not compel its use, either because of fatigue or poor digestion. And then the patient should not remain in it long, but quickly come out again. When, however, pain and discharge exist, one should anoint with remedies which are proper for clean ulcers, not corrosive, like the ash-collyrium and that of Cleon and similar ones. The eye must be regularly instilled with egg-white or woman's milk in a lukewarm condition. Benefit is also to be had from the instillation of a decoction either of bean-meal or of sheep's tongue or of purslane. For the pains in the temples we have the rose-collyrium of Nilus. When, however, we are obliged to resort to poultices, we may use those of poppy-heads, which should be light. It has already been said that poultices are to be avoided in a hot eye-disease. To the poppy-head remedy is to be added, in these cases, a little saffron and woman's milk.

"Chap. XXXIV.—*On Malignant Ulcers of the Eye.* Other malignant ulcers occur, beginning partly at the greater canthus, partly at the dark portion of the eye, partly at the white portion, and quickly consume the eyeball: especially when the bodily humors are acrid and the food is acrid also. From the ulcer runs an abundant, foul-smelling discharge, and severe pains and fever are added, and often a watery diarrhea. Sometimes the ulcer destroys also the parts neighboring on the eye. These consuming ulcers should be treated by the manner of living already laid down: only such things should be offered as do not purge. Hence these patients should use more the various kinds of poultry, especially the wild sort. Into the eye should be instilled white of egg or milk and the above-mentioned collyria. When, however, the devouring ulcer forces its way into the eye, one should employ the following treatment: the best flowers of zinc, washed, dissolved in woman's milk, to be rubbed in and followed by compresses, after one has rinsed away the suds with water and then with milk. Likewise efficient is white lead, washed and dried and then beaten up with milk, and dry lead dust which is procured by striking with a lead pestle in a lead mortar. Also effective is washed dross of lead and fine flour: each of these together with woman's milk. As regards poultices, in case we are obliged to resort to them, boiled quinces should be applied, or roses, fresh or dry, soaked in wine; sanguinary, nightshade, houseleek, succory, with barley meal. When, however, on the forehead and temples distorted bloodvessels appear, these must be divided.

"Chap. XXXV.—*On the Fly-Head* [small Prolapse of the Iris]. When the ulcers deepen, which arises from corrosion or laceration of the cornea, a part of the iris falls forward. The prolapse looks black or blue; while round its base the wound-margins of the perforated cornea look white. And, when the prolapse has become a little older, the margins of the rupture are more calloused, and, therefore, have to appear still whiter. In either case the pupil is distorted by the prolapse of the iris, so that it is either invisible or else is altered in its situation and form. Herein is the fly-head to be distinguished from the pustule. 'Fly-head' is the name employed, because the prolapse, in its form, resembles the head of a fly. It calls for corrosive and

astringent remedies, like those prepared from wine. In the same category belongs the following, which has been found of much service:

"Cadmia, copper, raw copper-ore, each 1 ounce; verdigris, 4 drachms; cavernous myrrh, 2½ drachms; saffron, 2 drachms; ammoniated rock-salt, 4 drachms; gum, 4 drachms: wet it all down with old sour wine. It is also effective for pterygium, epicanthus, trachoma, and also removes scars. In another author I found the following prescription, also for staphyloma: raw vitriolic ore, 12 drachms; rub it up with water, a spoonful; then add powdered saffron, 20 drachms, and rub it once again; then myrrh, 4 drachms; make of this a collyrium and employ it. After rubbing it in the eye, rub it also on the lids; lay upon them a delicate sponge and a bandage. Still another good remedy, also effective in staphyloma: raw vitriolic ore, 2 ounces; saffron, 1 ounce; gum, 1 ounce; rub it up with wine and use; for this affection, too, the Theodotian collyrium of Severus acts admirably. When the patient is free from pain, use it thicker; if there is inflammation, instil the remedy, especially the Theodotian, thinned with white of egg. To be added, in these cases, is a proper bandage. In inflammatory conditions, poultices are to be employed, of poppy-heads or fleabane soaked in warm water.

"The collyrium of Horus, effective against fly-head together with the Theodotian (it is also good for a chronic, thin discharge): cadmia, copper, saffron, hammer dust [particles of iron that fall from a forge], each 8 drachms; opium, 12 drachms; roasted vitriolic ore, ginger, gum acacia, gum, each 4 drachms; water.

"Chap. XXXVI.—*On Staphylomata.* There are various kinds of staphylomata, the causes of the disease being various. As a rule, however, in whatsoever way a staphyloma arises, it destroys the sight. It is called staphyloma when the cornea arches forward and produces a prominence resembling a grape. It arises, however, sometimes, when fluid accumulates beneath one of the layers of the cornea, and the cornea is then obliged by the fluid to yield, and, as it arches forward, to form a staphyloma, without tearing. This occurs also in consequence of a pustule-like formation between the layers of the cornea, which develops at a sufficient depth and which elevates the membrane, yet does not burst it. It is also, however, secondly, called staphyloma, when, after a laceration of the cornea a large prolapse of the iris has occurred. The latter case is distinguished from the former in this, that, in the former, there is present merely a protrusion of the cornea, for which reason the entire prominence looks whiter; in the second case, on the contrary, a rupture of the cornea has also occurred, and the prolapsed iris presents a blue or blackish color.

"If the staphyloma becomes very large, so that it extends beyond the lids, and hardens, while the cornea itself cicatrizes circularly round about it, snaring, as it were, that delicate structure; then it is called 'nail,' for it is just like the head of a beam-nail.

"In whatsoever way the disease arises, it is always accompanied by two disadvantages. First, the damage to the sight; second, the disfigurement in the personal appearance.

"To restore such a kind of eye to normal is impossible to our art.

The form and appearance, however, may be improved, particularly by operation.

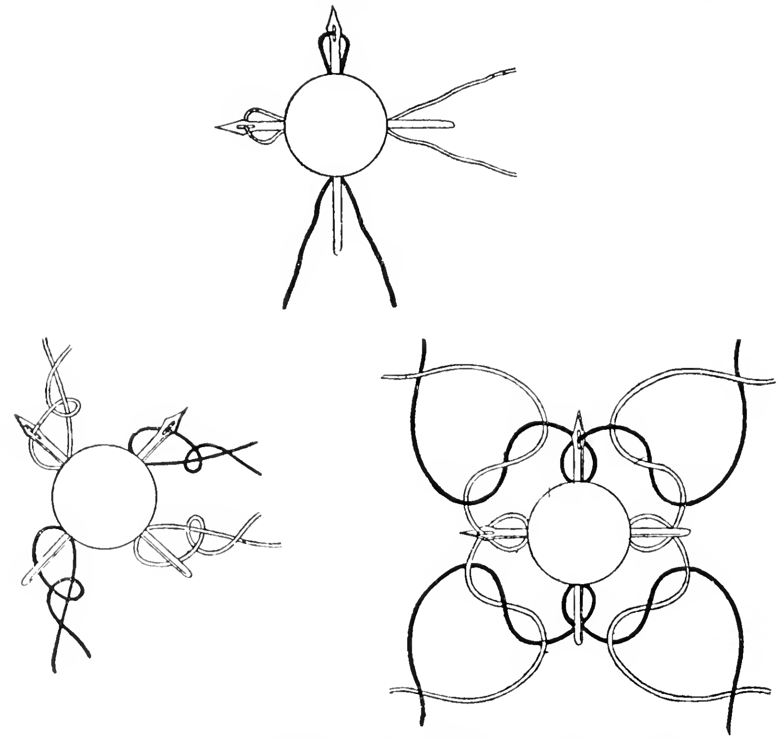
"One should treat all newly produced staphylomata, and when the membranes are arched forward by the ocular inflammation, with the poultices advised herein for ophthalmia and also by an appropriate way of life. Where, however, the entrance of a fluid beneath the layers of the cornea has produced the forward bulging, one should, in case pain is also present, make poultices of flaxseed and goatshorn, boiled in mead. As soon, however, as the pains have passed their acme, one should rub up bean flour with roses or with linseed flour in water or blackberry leaves, or unripe berries of bryony, with butter and turpentine in equal parts. Apply, and cover with a bandage. In those cases where there is still some pain, the instillation of nightshade juice with woman's milk is appropriate. As a collyrium after the inflammation, the following is suitable: seafoam [coral], 4 drachms; ammoniated rock salt, 1 ounce; saltpeter, 1 drachm; resin of the wild olive tree, 1 drachm; gum, 2 ounces; water. The Theodotian collyrium of Severus, beaten with cabbage broth, placed thick upon the eye, together with a sponge bandage, has caused the protrusion to disappear rapidly, in case the affection had become rooted. But difficult to heal are all those staphylomata, which possess a broader basis, and those which are shot through with blood-filled veins. Incurable are the nodular, varicolored sort, accompanied by pains in the temples. For such as these one should employ nothing at all but the pain-relieving remedies, which I have already mentioned when speaking of malignant ulcers.

"Chap. XXXVII.—*The Surgery of Staphylomata.* For such staphylomata as possess a narrow base and a benignant nature, operations are of use, especially those of which snaring forms a part. Its performance is carried out as follows: Two needles must be used, each with a loop of yarn thread, whose ends are of equal length. Then seat the patient and give him a correct position, bringing back his head against the lower part of your thigh; the occiput should rest upon your knees. While the lids are held apart, one should thrust one of the needles through the center of the base of the staphyloma, from above downward. The needle should be very thick and also not very long. While, then, the eyeball is immobilised by means of the needle which transfixes it, the second needle with the thread of yarn should likewise be introduced, from the lesser canthus toward the greater, also through the center of the base of the staphyloma, so that the two transfixing needles form the figure of a cross, or approximately that of the letter chi (X). For, if the transfixions are made somewhat oblique, the extraction of the needles (on a later day) is easier. Then we divide the head of the thread-loop, lay the two upper thread-ends beneath the upper end of the vertical needle, the two lower under the lower end, and tie each of the pairs of threads tightly together. In similar fashion we tie together the thread-ends of the horizontal needles.

"But the most elegant tying-off is done in this way: to tie, each time, a vertical thread with a horizontal.

"Next we abscise the apex of the staphyloma, leaving, however, its base, so that, when the threads fall out, the eye may not lose its contents and collapse.

"Now, why do we abscise a staphyloma? First, to secure prompter healing. For, when the apex is gone, the falling of the threads and



Ætius's Staphyloma Operation. First Stage. Second Stage.
(As Drawn by Magnus.)

the healing of the loss of substance occur more rapidly. Then, too, the patient is freer from pain during the entire process of repair, as the parts, being able to perspire, are therefore subject to no severe inflammation. But, after the removal of the staphyloma-apex, the needles must be withdrawn, the threads, of course, having been tied in the described manner. Then milk or white of egg should be instilled, followed by a dressing of wool soaked in beaten egg, oil of roses, and a little wine. Another pad, similarly moistened, should be placed on the temple, a bandage applied, and strict quiet enjoined. On the following day fomentations should be applied with well-squeezed-out sponges, milk should be instilled, and a pledget of wool saturated in white of egg should be applied; then a bandage. This treatment should be continued till the threads come away. When, however, the threads

are gone, mild collyria should be rubbed in, such as I recommended for ulcers, in order that the loss of substance may cleanse itself. Finally, cicatrizants should be employed.

"Chap. XXXVIII.—*On Ulcers which Require Cicatrization.* When ulcers in the eye have become clean, and require filling up, then care should be taken that they do not grow too luxuriantly, but rather cicatrize a trifle hollow, especially when the ulcer lies in the neighborhood of the pupil. For prominent scars interfere with vision, damage the personal appearance, and, as a rule, because of the friction of the lids, occasion ocular discharges. Those, however, which appear a trifle hollow, are not only more easily penetrated by rays, but look better, inasmuch as they harmonize with the color of the surrounding parts. And this they become, if we pass straightway from the soft and filling remedies to those which cicatrize. Should they, however, once (unsuspectedly) have grown too far, it is better to astringe immediately and to thin the proliferations, and then to cicatrize. Such remedies must be avoided as stain the scars, especially when the ulcer lies in the pupillary area, for, if they are blackened, they disturb the vision still more.[64] Then, too, should be avoided the ocular bandage, which a few employ in order to keep the ulcer on a lower level; for, if an ulcerous eyeball be bound and held immovable, it very often becomes adherent to the lids.

"One should be able to recognize with certainty all cicatrized ulcers. Many physicians, however, fall into error, taking concave scars for excavated ulcers and then anointing with soft and filling collyria. Then it happens not indeed that the cicatricial parts fill out, but that the ocular membranes, as a result of such treatment, become hypertrophied. When, then, you see that the surface of the place has become shining, white, and smooth, while at the same time the white of the eye has taken on its normal color, and the entire eye is free from secretion; then know that the course of that ulcer has been run.

"The best collyrium, however, which we possess for ulcers in need of cicatrization, is that of Cleon.

"Chap. XXXIX.—*On Scars, or Leucomata.* All scars on the dark of the eye appear white, for the cornea is made thicker by the scars, and therefore does not let the dark color from below shine through; but convex ulcers are nearly always white, the level less so, and the concave blend to a certain extent with the color of the dark of the eye. All those which were treated by astringent remedies until the close of cicatrization, shade the pupil more strongly, because, by the astringention, the members are thickened.

"But calloused, inveterate or hypertrophied scars should not be treated at all. For, of necessity in such cases, the very sharp collyria are used, and, by their strongly corrosive action, the other parts of the eye may be injured. When, moreover, at the same time, hypochyma or glaucoma exists, it would be entirely in vain to wish to remove the scars.

"Whosoever, now, would diminish the scars a trifle, must, before all, prepare the body by a correct way of living, in order that the material

[64] The very opposite is, of course, the truth.

of the entire body should be present in right quantity and correct mixture. The patient should therefore avoid everything acrid, salty, and oversucculent, as well as too great indulgence in wine, and to tend to good digestion before all things, and partake of moderately nourishing food, refraining from the bath at the time of treatment. He should anoint the eye before taking nourishment, if his digestion is good, and his head and whole body are light, after the opening of the bowels, but never either immediately after rising or before the chief meal. Denuding remedies are to be avoided. Some physicians are accustomed to anoint the eye with acrid remedies and to skin the scars, and to take the pellicles away with sponges and to exhibit the white masses about on black whetstones; then they anoint with one of the remedies which stains the scars. When, however, discharge is added in consequence of the acridity of the remedy, and inflammation, and occasionally the scars break down, then the ulcers become very much deeper. Then such physicians are obliged to use again the astringent and obstructive collyria and so they produce only a still greater thickening of the scars.

"Chap. XL.—*Remedies for the Thinning of Scars and Leucomata—According to Galen.* For such scars as permit of thinning, should be employed the moderately cleansing remedies. The strongest purification is effectuated by annealed copper, copper hammerings, flowers of copper, and annealed copper ore. When these remedies are washed, they still keep indeed their purifying power, but in just so much the less a degree as they also lose their cauterizant action. It is safer to employ less corrosive substances. Stronger, however, than those named are vitriolic ore and verdigris, so that they are properly added to remedies for the fig-disease of the lids and the indurations which arise therefrom. A few physicians add also gallapples, a powerfully astringent remedy. Still stronger in tanning-power and at the same time in cauterisant action, is blue vitriol. The latter becomes much milder after annealing and washing. Also the particles of steel which fly from the anvil possess the same properties. All the astringent remedies possessed of an earthly character have the power of melting away trachomata and their fig-formations and callosities. To this class belong vitriolic ore, verdigris and the like. All substances which belong to the class of plant-juices, such as the juice of unripe grapes and of cytinus hypocistis and of celandine and of acacia, are, when placed on the eyes, swept away too easily by the tears. A cleansing action without corrosion is possessed by burnt stag's and goat's horn. Frankincense has but little purifving power; it is anodyne and maturating. The horns of the animals mentioned are indeed cleansing, but they exhibit neither anodyne nor maturating power, for they possess a cold and dry nature. The bark of the incense tree astringes very beautifully, but still, in this respect, is far behind the others mentioned. But the tiny fragments of frankincense which have been crumpled in the parcels, which one is accustomed to calling manna, are distinguished from the pure frankincense in this respect, that they have acquired a slightly astringent effect, inasmuch as they contain an admixture of small particles of the bark. The so-called Armenian

[carbonate of copper], which painters use, has a purifying effect, and indigo black, and may therefore be employed with impunity for ulcers free from inflammation. Aloe displays a mixed effect, just like roses, for it possesses a bitter substance, which, in accordance with its nature, possesses the power to purify; it possesses in addition an astringent power, which cleanses ulcers and cicatrizes them. But ammoniated rock-salt and muddy stone belong to the strongest remedies, so that they show themselves appropriate for marginal ulcers. Of the aromatic remedies there are properly added to these, cassia, betel, and amom, which indeed exhibit a dispersive effect, but, in addition, a certain amount of astringency. In general, one should know exactly, as regards purifying remedies, which of them display a moderate action, and which of them melt away fig-formations and callosities: all the latter are also appropriate for thick scars.

"Chap. XLI.—*Remedies for Scars and Leucomata.* For leucomata take the seed of fever-root (whose seed is hidden in the earth and is like that of pepper), pulverize it with honey, and use as an ointment. Another remedy for scars and weakness of sight: rose-seed, 2 scruples; armeniacum, 7 scruples; ammoniated rock-salt, 3 scruples; ammoniated frankincense, 3 scruples; use as powder. Another, which removes fresh scars painlessly: horse-milk with a little honey regularly rubbed in. Rub up the light, purple-colored blossoms of anise with a little water, strain this through a linen cloth, and drop the juice into the eye twice a day. Then chew up the seed of a garden cucumber, squeeze the juice through a linen cloth, and instil it into the eye, and do this continuously.

"Another remedy for leucoma. Pulverize vervain root, and insufflate it. Then hold the eye tight with the hand, and, for a short time, affuse it with cold water.

"Milesian sea-foam with honey cleanses the scars well; also ammoniated frankincense, pulverized with wine and honey.

"When, however, a sucking child gets a leucoma on the eye, its mother should chew up ammoniated frankincense, and insufflate it into the suckling's eye. The root-bulb of anemone, powdered and blown in, is also effective, and the juice of the blue-flowered anagallis, with honey.

"Another. The juice of fumitory, the so-called swallow-wort, with honey. Natron with old oil.

"The juice of garden-mint is wonderfully effective. Dove's dung, beaten up with water on the whetstone, is, when rubbed in, effective beyond all expectations, likewise the gall of a cat. Another for leucoma, almost infallible: melted butter, rubbed in of itself; it works beautifully, only try it; one need not promise more, because the remedy overtops all promises. Another, most excellent: woman's milk, verdigris made of old nails and vinegar; good honey; mix the three ingredients in equal parts, filter the mixture, and use it as if it were a divine remedy. Burn the seed of sorrel or of sheep's tongue on a potsherd, powder the ash carefully, and use. Another: saffron and pepper in equal parts, powdered and rubbed up with cat's gall into a collyrium: use. Another: tear off the heads of young swallows; burn

them in a pot; powder the ashes, and take them up in a box made of horn for use. For this remedy is very useful, even for an ocular injury, if rubbed along the edges of the lid. Another: the so-called flesh-eating stone,[65] from which the larger coffins are made; pulverize; sift; rub up with saliva (the best is that of the patient himself, fasting) and rub this in boldly. Another remedy for scars and leucomata: take the gall of a heifer calf, perhaps a cup full; boil it a little over an open fire; add an equal quantity of the best honey, 2 drachms of myrrh, 2 drachms of saffron; rub it all together, and boil it again sufficiently long in a copper skillet, and take it up in a copper box for use. Another: of magnetic iron, ophites, and antimony, equal parts; grind up; sift; rub it again very industriously; add to it the juice of batwort and best honey and anoint it, best by means of a sound which has been prepared from sarcophagous stone. Another: resin galbanum and honey; melt; rub together; use. Another collyrium which removes leucomata wonderfully and rapidly: iron filings, 2 drachms; fibrous alum, 2 drachms; worm-shaped gum, 3 drachms; rub up with water; make collyria and use. Another: goat-thorn juice (when possible, from the fruit; otherwise, from the leaves), 2 ounces; ammoniated frankincense, 1 ounce; cuttle-fish scales, 1 ounce; attic honey, 2 ounces; take up the powder in the honey; use. Some, however, rub up only the ammoniated frankincense with the goat-thorn juice and apply this. The juice alone, rubbed in, stains the scars. The collyrium of Archigenes for leucoma, which, after a single application, takes away the greater portion of the leucoma; it works also wonderfully well in dangerous and tedious ophthalmia: burnt mussel shells, 3 drachms; burnt copper, 4 drachms; copper hammerings, 6 drachms; iron-filings, 12 drachms; verdigris, 6 drachms; fibrous hematite, 1 drachm; aloes, 1 drachm; dried unripe grapes, 2 drachms; catechu, 4 drachms; copper ore, 3 drachms; myrrh, 3 drachms; frankincense, 3 drachms; bark of frankincense tree, 2 drachms; saffron, 2 drachms; saffron fiber, 2 drachms; spikenard, 3 drachms; pomegranate calices, 2 drachms; gum, 8 drachms. Rub this up with water, form collyria, and employ the collyria with water. And if you wish to apply a dry remedy, then rub up that dry collyrium and use the dry powder. Apollonius says that the compressed collyrium is especially useful for scars. The Harmation is also effective, and the collyrium already described, made of wine and employed for fly-head, as well as similar ones which shall be communicated in the chapter on the composition of the usual collyria. The Theodotian remedy of Severus, with water, thickly applied, brings the scars to such a degree of attenuation that they can as a rule no longer be perceived by the senses. The best dry remedy for this trouble is that called the remedy of King Alexander, prepared from saffron, Celtic nard and vineyard-earth. It is treated of under the customary dry remedies.

"Chap. XLII.—*The Staining of Leucomata.* I have already suggested that one should avoid such remedies as stain the scars; however, in order that one may not overlook those which are able to do this, it is necessary to enumerate them here.

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[65] A calcareous stone which quickly consumes the flesh of a dead body.

"Gallapple, powdered, says Galen, keep well preserved. And, when about to use it. warm the head of the sound and take upon it a little of the remedy and rub it into the leucoma. Then dissolve chalcanthus in water, and apply this also.

"Another. Paint with powdered pomegranate peels, then copper vitriol with water. Another: pulverize the pulp of sweet pomegranates, trickling a little water upon it, and when you have prepared a very fine powder, take it up. When, now, the remedy is to be used, you must previously macerate the part frequently with this powder, and then rub in henbane juice for 15 days: that colors the leucoma and makes it invisible, if enough is rubbed in. Another remedy, also effective for blue eyes: rub up vitriolic ore with water, and form collyria. Likewise form other collyria of gallapples. At the time of use, however, macerate first with the gallapple preparation, and then rub in that from the vitriolic ore.

"Another dry remedy: gallapples, 1 drachm; gum acacia, 1 drachm; vitriolic copper, 2 drachms; use. Another remedy, in fact a collyrium, is the following: pomegranate blossoms, gum acacia, gum, each 4 drachms; antimony. 4 drachms; gallapples, 2 drachms; water. When, however, the blossoms of pomegranate are not to be procured, add the membranous masses which lie in between the berries.

"Chap. XLIII.—*For Blue Eyes; to Provide Them with Black Pupils.* Pour in juice from the rind of sweet pomegranates. Then, after a time, instil the blue blossoms of henbane rubbed up with wine, or henbane juice. One must, however, gather and take up the blossoms at a fitting time. Another: rub up carefully the fruit of the acacia-tree and a little gallapple: take this up with the juice of the anemone, until it acquires the consistency of honey; then press the liquid carefully through a cloth, and take it up and use it according to directions.

"Another: anoint blue-eyed women with the juice of wild cucumber. That makes them black-eyed.[66] Another: take the blue blossoms of henbane, dry them in the shade, and take them up. At the time of use, macerate the flowers in crude wine, and rub in at first the liquid part, later employ the flowers themselves, after proper pulverization, under the lids. It is instantaneously effective.

"Chap. XLIV.—*On the Treatment of the Newly Born—According to Severus.* A fearful disease occurs in the eyes of the newly born. Commonly, the lids swell from the quantity of matter. For moist and warm by nature are the newly born. The collyria for this disease must be cooling and drying, but at the same time properly astringent, in order to overcome the flow of ocular secretions.

"Up to a certain degree of astringent effect, the collyria for children have been used. so that they occasionally overcome even trachoma. For the acridity of the collyria is dulled in the newly born by the moisture which is peculiar to them and by the quantity of ocular secretions, and, in addition, the collyria are washed out of the eye by the great quantity of tears due to the additional crying.

"For me there has been approved, in these cases, as the first and

[66] I. e., dilates their pupils.

most wonderful collyrium, that which contains schistous hematite, 20 drachms; hematite, 20 drachms; verdigris, 4 drachms; roasted copper ore, 4 drachms; annealed copper, 4 drachms; opium, 6 drachms; myrrh, 6 drachms; gum, 16 drachms. This composition of the collyrium is as well approved by reflection, as it is recognized to be of use by experiment. It is rubbed up with water. Another collyrium, too, has shown itself of value for the same affection. It contains schistous hematite, 24 drachms; hematite, 24 drachms; annealed copper, 8 drachms; ammoniated frankincense, 8 drachms; roasted vitriolic ore, 8 drachms; opium, 4 drachms; henbane seed, 4 drachms; gum, 8 drachms; water.

"Then, too, in the beginning of this disease, there should be added some from among the non-corrosive collyria, and so gradually passing to the remedies of more powerful effect. Wonderfully effective is the collyrium of Theophilus, and the so-called 'Sound medicine.' I have spoken of this in the chapter on the customary collyria.

"Chap. XLV.—*On Trachomata, Rawnesses, Fig-Formations and Callosities—According to Severus.* Inasmuch as the judgment takes into consideration an affinity in remedies, and, so to say, has discovered medicinal powers which are suitable one to another it is obliged to set a limit to these, and not to permit that we interpolate something heterogeneous. The granules, then, which many also call 'rawnesses,' arise, often, as a result of unskilful treatment, for they appear when physicians make too many instillations. Just as, in the case of external injuries, inunction produces proud flesh, in the same way, in the disease which is under discussion, the origin is to be conceived. The disease also arises after chronic, non-acrid discharge; for, were it acrid, it would destroy the eye before it engrafted this disease on the lids. The affection also arises sometimes without preceding discharge, and without the presence of any obvious cause. And these cases are in no way similar to those arising from discharge; for, in the cases first described [those from catarrh] the everted lids look somewhat raw, granular, and reddened with blood, while, in the cases which arise without discharge, one sees as it were little grains of millet, or small peas, protruding on the inner surface of the lids; and this kind is harder to cure than the others. Furthermore, one should, in these conditions, make the following distinctions: 1. The nappiness is superficial and accompanied by redness. 2. In the granular condition the alteration and prominence are greater, simultaneously with pain and heaviness; both conditions are united with humectation of the eye. 3. The so-called fig-formations show still higher elevations which appear as if notched, and resembles nothing else so much as a fig that has burst. 4. The callous formation is an inveterate roughness, or nappiness, and shows the altered parts hardened and calloused—a few physicians try to shave off the asperities, some with the knife, others with fig leaves. But this attempt is very harmful; for, as a rule, in that way the formations are increased and hard scars produced, together with an obstinate discharge, in addition to which the eyes are always irritated by the hard scars which have been added—the granules, in case no ulcer is present on the eye, should be treated in this way: One should, with the remedies for nursing children, already mentioned,

when there is no inflammation, evert the lids and anoint them, and massage them for a long time with the head of a sound, for, if one leaves off rubbing too soon, one produces greater roughness and discharge. If the injurious cause continues, stronger medicines must be employed, as for example the following: cuttle-fish scales, 8 drachms; pumice, 8 drachms; sinopic red-chalk, ammoniated frankincense, each 10 drachms; gum, 8 drachms, dissolved in water. By the use of this remedy, you will acquire the greatest reputation; for, immediately after the inunction, a few pieces of the superficial pellicle come away under patting. One should, however, after the use of the remedy as an ointment, cleanse the parts with cold water by means of a sponge.

"There is yet another remedy for these diseases. It contains cadmia, 4 drachms; copper hammerings, 4 drachms; ammoniated rock-salt, 4 drachms; opium, 2 drachms; gum, 12 drachms; water, q. s.

"I, however, have found the dry collyrium of Severus exceedingly useful, and a trial will teach you also its value.

"Apollonius says that such remedies are to be employed for lid asperities, as those with which we purify the thickest scars, as for example the following: annealed copper, 8 drachms; myrrh, 1 drachm; copper hammerings, 1 drachm; gum acacia, 2 drachms; cadmia, 2 drachms; spikenard, 1 drachm; cinnamon, 1 drachm; saffron, 1 drachm; pepper, 16 grains; hypericon, 3 drachms; ammoniated frankincense, 3 drachms; verdigris, 2 oboli; gum, 1 drachm. Rub it up with old, crude wine, and form from it collyria for use.

"Another remedy for old discharge and lid-asperities: cadmia, 16 drachms; annealed copper, 4 drachms; henbane seed, 1 drachm; opium, 2 drachms; myrrh, sweet-broom, gum acacia, each 4 drachms; gum, 8 drachms; all dry and finely powdered. Rub this up with woman's milk and form collyria. Rubbing this up also with woman's milk, use it thick as an ointment, after preliminary fomentation.

"A moist trachoma remedy, which is good also for hypopion: roasted copper ore, 3 drachms; saffron, 8 drachms; honey, 9 drachms. Rub up the dry substances with water, and, when the mass has again become dry, add the honey and use.

"The so-called eye-salve of Theophilus for fig-like elevations and all proud flesh: annealed copper, 2 drachms; roasted vitriolic ore, 1 drachm; myrrh, saffron, juice of unripe grapes, each 1 drachm; Chian wine (or another which is cruder, older, and better-smelling), 16 ounces; Attic honey, 10 ounces.

"There are also other collyria which are good for trachoma, as for example the Phoenix and the Dionysos and the like, which I will describe in the chapter on the usual collyria.

"For those persons in whom, at the same time with the asperities of the lids, the membranes of the eye are painful from inflammation, one should add to the specific remedies for ophthalmia a little of the purifying remedies. In this class belong those made of wine, which are yet to be described. When, however, the parts of the eye have become free from inflammation, one must proceed to the removal of the asperities. For those, however, who have an ulcer with acrid discharge, we are not in a position to employ such a remedy. For the

cornea will be more strongly corroded, and the prolapse of the iris will enlarge, and still more grievous pain will afflict the patient, and even the corrosive discharge will be made worse.

"For such patients the following collyrium should be prepared. We reduce pumice to the very finest powder, and take it up in macerated tragacanth or gum, and form from it small collyria. Then we gently turn the lids and rub them for a long time, finally instilling milk and using the customary collyria for pustules and ulcers. When, however, in time, the discharge yields, we pass to the sharper collyria, massaging the lids with them as described. We then mix with the collyria appropriate for ulcers those made of wine, gradually strengthening the mixture, so that, on the one hand, the asperities of the lids do not become troublesome to the ocular membranes, while, on the other hand, the ulcers, after they have been made clean, fill up and cicatrize.

"Chap. XLVI.—*On Atony of the Eyes—According to Demosthenes.* These eyes are called weak which do not bear to look at white objects, or shining ones, or those which are fiery, but, when this is attempted, close the pupil and lacrymate: these things they do especially after much reading. They are to be distinguished from cases of epiphora in this way: that the latter produce tears without external cause, the former, however, only when such a cause is present. Weak eyes should be treated by the promenade, by protracted running, with gymnastics of the upper extremities, with massage and holding of the breath, with shearing of the head and light massage of the eyes after the gymnastics and with affusions of cold water to the head. Also to be prescribed is water-drinking and a temperate manner of living. It is also useful to read with a loud voice, and to write. In case we are obliged to resort to local eye-remedies, we shall use the astringent, the cooling, and the obstructive.

"Chap. XLVII.—*On Shortsightedness* (myopía). Those are called shortsighted who, from birth onward, see small and near objects, but are not able to see those which are large and distant, and who, when reading, bring the script up close to the eyes. A few of them have irregular, bulbous eyes, others, however, normal eyeballs. The condition is incurable.

"Chap. XLVIII.—*On Nyctalopia.* One speaks of nyctalopia, when anyone can see by day, but sees more badly after sun-down, finally, when the night has come, sees not at all. The cause of the disease may be a weakness in the head, and especially thickening of the optical pneuma and of the other humors and membranes of the eye.

"Other persons, however, see better by night and worse by day, while if, at night, the moon shines, they do not see at all. But this disease is rare, the former frequent.

"Nyctalopic persons should be treated, if robust, with venesection at the elbow, and at the corners of the eyes, but, when the humors are corrupt, by purification with a proper purgative. Then, after the general evacuation of the body, gargles should be employed, and purification should be practiced through the nose, and sneezing excited. As a nasal remedy the following is proper: pepper, lousewort, each 2 scruples; mustard, 1 scruple; pulverize, sift, add as much juice of the

white-beet root as is needful to bring to the consistency of liquid honey; rub it together, instil it into the nose and let it draw the nose open. This do for from five to seven days. Also, use the other nasal remedies which have already been communicated in the chapter on nasal diseases. The patient should take before meals, hyssop, organy, and rue. The manner of living should have for its object the reduction of the bodily weight. When, however, all this fails, one should give again a purgative, for example this: scammony, 3 oboli; beaver gall, 2 oboli; salt, 3 oboli. In case of great physical weakness, only 2 oboli of scammony should be used. This purgation has often freed the patient quickly from his disease, or, at all events, produced a decided improvement.

"A few days later a different purgative should be given—one which brings away mucus and gall, for example this: bitter apple, 2 oboli; scammony, 4 oboli; aloes, 4 oboli; make of this six pills and to those who are moderately constipated give 3, to those more strongly affected, all 6.

"Boiled honey should be rubbed in the eye, and the eyes held closed in order to retain the fluids. Very old oil may be used in the same way, or indeed fibrous alum roasted on a potsherd, 2 drachms; ammoniated rock-salt, or the Cappadocian, 1 drachm, rubbed up with honey and woman's milk. Or hyena gall with honey. The continued use of acrid remedies should be avoided, but old oil should be persistently used. Goat's liver appears to be of use to these patients, with salt, but roasted without oil and eaten very hot. Others, however, are accustomed to anoint the eye with the broth which exudes from the liver during the roasting; others, during the roasting, have the eyes held open in the uprising steam and so foment them.

"The wild cucumber is also of service, rubbed in from time to time with honey, and the gall of a partridge, or of the wild she-goat, or of the he-goat. Then, too, the gall of the sole-fish, rubbed in, proves of great service. But, as stated, the entire way of life should be such as to make the humors thin. In the beginning one should refrain from wine, and avoid everything of a thickening nature [i. e., which thickens the bodily 'humors']. In those who see better by night and worse by day, I take it that the pneuma is very thin or the membranes leaky, and that the dispersion of the pneuma which occurs by day, makes the pupil blind, while, by night, a gathering together and thickening of the pneuma occurs, so that it then is in a condition to arouse the sense-perception. Therefore, one ought to provide for these day-blind persons a greater firmness in the eye. Herophilus, on the other hand, says in his work on ophthalmology: 'For dayblindness take of gum, the dung of the land-crocodile, vitriolic ore, and hyena gall, rubbed up with honey, and rub this into the eye twice daily; and give the patient to eat nothing but he-goat liver.' I suspect, however, that this works better for nightblindness.

"Chap. XLIX.—*On Amblyopia—According to Galen.* Amblyopia is a dimming of the vision, and arises from various causes: either because the optic pneuma inspissates, or the membranes condense and thicken, or the ocular fluids become thick and tough. Visual weakness

also occurs in those afflicted with tedious bodily diseases, and in consequence of heavy grief. In extreme old age there is generally added to the inspissation of the ocular fluids and of the membranes of the optic nerve, also relaxation of the optic pneuma and decided diminution in its quantity. Also collapse and a kind of rumpling of the optic nerve and of the condensed and thickened ocular membranes. For, as the ocular fluids diminish in the aged, and less pneuma streams down from above to the pupil, the cornea waxes rumply to such a degree that, of the aged, some do not see at all, while others see indeed but badly and with great effort.[67] For the folds lay themselves one upon another, and the membrane doubles itself to a certain extent and assumes a newly acquired thickness. The remedies for persons with amblyopia are made of the same materials as for those who have incipient cataract [hypochyma]; some of which are used in the form of collyria; others (which are also good for inflammations of the ocular membranes accompanied by thickening) are moist; still others are dry. Their preparation will be shown at the close of this section.

"Chap. L.—*On Amaurosis—According to Demosthenes and Galen.* Amaurosis is the absolutely complete obstruction of sight without any visible alteration in the eye, the pupil of course looking clear. In some cases the affection develops very gradually; in others, however, it attacks suddenly, so that the patients see but a minimum or, all at once, see nothing at all. There are several causes for the blindness which develops gradually: these we have already mentioned when speaking of amblyopia. For the blindness which comes on suddenly, the cause is obstruction of the optic nerve, thick and tough exudations, that is to say, coming into it suddenly, or the paralysis of the nerve itself. Preliminary to the disease are chronic digestive disturbances and the misuse of wine. Siriasis, overheating or overcooling of the head or uninterrupted reading after meals, or, similarly, continued bathing after meals, or immoderate and unseasonable vomiting. Coitus and violent holding of the breath, such as takes place in trumpeters. These and similar injuries are accustomed, if they remain moderate, to produce amblyopia, when excessive, however, amaurosis. Amaurosis also follows, sometimes, violent injuries to the head, and falls from a great height, the optic nerve being occasionally paralysed or even avulsed, or (which is the mildest of all these) by the violent concussion a superfluity of moisture is brought into the nerve, which is thus obstructed. In paralysis of the nerve, difficult motility or non-motility of the eyeball results. When, however, in consequence of a violent injury to the head, or a fall, the nerve tears away from its adhesions to the brain, then occurs first prolapse of the eyeball, afterwards enophthalmus and atrophy. When, however, through an excess of thick, tough exudation, the canal in the optic nerve suddenly undergoes obstruction without apparent cause, then, of necessity, a sensation of heaviness in the head occurs, particularly in the depths at the roots of the eyes.

"Those who are blinded suddenly should be treated with phlebotomy

[67] Chiefly because of the lack of spectacles in those days.

at the elbow, if the patient be plethoric—for phlebotomy is the speediest remedy. Then a few days should be suffered to elapse, after which a ligature is placed around the neck of the patient and tightened until the vessels of the forehead look tortuous. Then the ligature should be loosened and tightened again for two or three times, in order, by means of the motions of the pneuma and fluids, to jolt the obstructing matter vigorously. Then the two meandrous veins at the internal canthi, one on each side of the nose, should be divided, and a strong evacuation of these produced. I have removed at one time as much as three glasses from the canthal veins. Then a wet cup should be applied to the occiput. In fact it often happens that immediately, while the cup is still in place, the patient recovers his visual power.

"But it is not permissible to be satisfied with this therapy: when the patient has regained his strength, he should be purged and then dieted. But in those cases in which the blindness came on slowly for a long period, we perform (after a preparatory diet) a phlebotomy of the canthal vessels in the way described. Then we set a cupping glass on the occiput, afterward purging. With respect to the mode of living, the bowels should be kept liquid by the nourishment, and good digestion should be carefully secured. For a number of days aloes should be administered, which is used in pill form by means of turpentine. Zaffer juice with honey is also good. Moreover, gymnastics of the lower extremities should be prescribed and abundant walking in sheltered places.

"Indulgence in wine is to be avoided, and the drinking of water endured with manly fortitude. Also to be avoided is every kind of thickening nourishment, frequent coitus and illumination of the head. Also, the bath should not be taken too frequently, or a sleep in the daytime, or much motion indulged in after meals, or reading or writing. The patient should especially guard himself against intense anger, excitement, care and great fright and anxiety, especially after meals, and also against continued vomiting. One should affuse the face daily with cold water, especially with rainwater, and permit the entire body to be anointed by others. When the affection is inveterate, one should purify the head with nasal remedies, instilled into the nostrils, as recommended by me for headache, and also employ the gargles cited by me in the same place. The inunction of the eye, in cases already chronic, should be made at first with simple remedies, for example with unsmoked honey and old oil; later the compounded remedies should also be employed. I, however, have acquired reputation by prescribing for these troubles the 'Perforation Collyrium' and that for hypochyma [cataract] of Aglaides.

"The following is a common remedy for amblyopia and amaurosis, and appears to be good also for thickening of the ocular membranes: saffron, 1 drachm; ginger, 1 drachm; pepper, 15 grains; spikenard, 2 oboli; fennel juice, 16 drachms; ammoniated frankincense, 1 drachm; honey, 5 ounces. Powder all as finely as possible, and then add the fennel juice. Rub up, dry, add the honey, and take it up in copper boxes, ready for use. But, before the inunction, the eyes should be fomented with a sponge dipped in warm sea-water; occasionally, too,

the face should be dipped in lukewarm sea-water. That is the usual treatment for all cases of amaurosis. But especially in those cases in which, from the pressure of abundant or thick exudations, which have cast themselves upon the optic nerve, the vision is obstructed, one should place a mustard plaster on the head, after the venesection, the cupping and the purging. then, too, he should produce with some corrosive substance an ulcer on the back of the head, and employ warm affusions over the head—and it is better if salty, or soda-containing, water is used for the purpose.

"Chap. LI.—*On Ocular Paralysis.* Not only the optic nerve, as already indicated, but also the entire eyeball is now and then paralyzed, sometimes in conjunction with paralysis of the right or left half of the body. Occasionally the paralysis is limited to the lid, but sometimes the entire eyeball is stricken. And when the lid is paralyzed, the eye remains always closed. and the lid is anesthetic. When the entire eyeball is paralyzed, it cannot execute motions toward either side, or upward or downward; and, if an acrid substance be rubbed into the eye, no pain is felt.[68] When there is only paralysis of the lid, we must first of all purify the whole body, and employ the aloe-remedy and water-drinking, together with much promenading and massage of the lower extremities, and anoint the lid regularly both with schistous alum mingled with sharp vinegar, and also with the more acrid collyria or that made of red lead. If, under this treatment, the affection does not yield, then one must elevate the lid by sewing.

"Paralyses of the eyeball are hard to heal, especially in old persons. When the affection is congenital, it is not susceptible of cure at all. For those cases, now, in which there is any hope of cure, we must employ the following remedy. Before all, if the patient is robust, the performance of venesection at the elbow, then the rinsing out of the bowel, then the evacuation of the bowels with a purgative. Then the employment of gargles, then the purification by nasal remedies, then, finally, the setting of a cupping-glass on the occiput and leeches to the temples. Before this, one should give beaver-gall, by itself and also with absinthe and with hyssop and pennyroyal, also rue with honey-vinegar and salt. Then the head should be anointed with beaver-gall commingled with oil of roses and vinegar, and a little of the same salve should be taken up on soft wool and laid upon the closed eye, care being taken that none of it gets into the eye. This treatment must be employed twice daily. Also the lids should be anointed externally, as well as the forehead, with beaver-gall mingled with saffron and vinegar. The ointments made of beaver-gall and honey appear to me suitable for this disease; and these should be rubbed both on and in. Wine should be abstained from and meat diet, as well as every sort that strongly nourishes and makes thick humors; on the other hand a diet should be chosen which makes the secretions fluid and which thins the humors. In the beginning one should also avoid the bath, the sweat bath, and illumination by the sun. Vomiting is at times to be employed, in a fasting condition, by

[68] As Hirschberg remarks, "Aëtius appears to assume that paralysis of motion and sensation are always found together."

means of cooked radish, and with bandaged eyes, and without much retching.

"Chap. LII.—*On Glaucoma.* The name glaucoma is employed in two senses. Glaucoma proper is a coloration of the crystalline humor to a sea-blue, together with a drying and hardening of that structure. The other kind of glaucoma arises from cataract formation, the exudation becoming hardest and most dry in the pupil. This latter kind is incurable. Glaucoma proper can, sometimes, in the beginning, be cured by the employment of promenades in proportion to the strength of the body, and massage of the whole body and affusion, especially to the head; in summer one should also take cold baths. Moreover, the head should be shorn to the skin, and the eyes anointed with old oil only.

"Chap. LIII.—*On Cataract—According to Demosthenes.* Cataract is an effusion of exudate, which hardens in the pupil, so that, when it has become complete, it abrogates the sight. But in the beginning of the formation of a cataract the following happens to the patients: It appears to them as if little flies and tiny dark bodies continually floated before the eyes; a few see formations resembling hairs, others things like threads of wool or spiderwebs, to others circles appear about the flames of lamps. While these phenomena are present, the pupil seems at times to be entirely clear, at least to the careless observer; sometimes it seems to be of the color of the sea. While, however, the disease progresses, the phenomena also increase. And when it is complete, the patient sees no more, and the pupil is changed in color to a kind of white, and is no longer transparent at all. There are various kinds of discoloration. Some of the cataracts are of an atmospheric-blue, others glass-green, others entirely white, still others dark blue; others, however, become water-blue, and these are incurable.

"Those who are afflicted with cataract should be treated by means of phlebotomy at the bend of the elbow, if nothing contraindicate, and with the more drastic clysters and purgatives. Then, too, wet cups should be applied to the occiput, and gargles should be employed from time to time, as well as errhines. The patient must, however, abstain from the use of wine throughout the whole period of treatment, also from everything which overfills the head, and from the bath, except when this is necessary by reason of weakness and slow digestion. And even then he should not linger in the atmosphere of the bath, nor remain very long in the tub, but get out soon and promptly go away.

"The entire regimen should be directed toward lessening the body weight. Of medicines there should be employed at first the simple ones, like honey and old oil and fennel juice, afterwards the compounded moist and dry medicines and collyria, which I shall soon describe in the chapters on the general materia medica of the eye.

"Chap. LIV.—*On Mydriasis, or Dilatation of the Pupil.* Mydriasis and dilatation of the pupil are names applied to the condition when the pupil, though it has kept its color unchanged, has yet become much larger than normal, so that it now and then approximates the circumference of the cornea; and occasionally abrogates the vision absolutely. In other cases the patients do indeed see, but as if in the dark,

and the objects seen all appear to them to be as if minified, since indeed (as a matter of course) the optic pneuma expands too widely.

"The cause of the disease is an effusion of liquid. This may happen either very suddenly or very slowly; imperceptibly the iris draws itself apart and the pupil enlarges.

"The disease is very hard indeed to cure. For, as the iris is nothing but a thin membrane, it must, when once drawn apart, become indurated, and then cannot easily contract again. The disease attacks more frequently small children, because of the tenderness of their membranes. Persons with black eyes have naturally a large pupil, for which reason they incline to this affection.

"The disease should be treated, in the absence of contraindications, by means of phlebotomy at the bend of the elbow, or with purgatives. When, however, it seems impossible to do this, the veins at the canthi ought to be opened, and then a cupping-glass be set upon the occiput. Restful, frequent promenades should be taken in sheltered places, and in every way the matter should be drawn to the lower portions of the body. Hence, in the beginning, the clyster should be employed, and massage of the lower extremities by the hand of an assistant. After the promenade and inunction of the body the face should be affused with sea-water (lukewarm in winter, cold in summer) and the entire face should be dipped in the water for a time while the eyes are being held open. When, however, sea-water is not at command, one should employ sweet water to which has been added a little salt, or else very much diluted vinegar-water. And the whole way of life should be directed toward the thinning of the humors and the keeping of the bowels open, while the bath should be but seldom taken, and never in conjunction with affusions to the head.

Of local remedies one should employ only the slightly astringent, as roses, saffron, nard, frankincense bark, flowers of zinc, metallic ashes and gum acacia. For very acrid remedies attract a superfluity of liquids, drawing the membranes apart and enlarging the pupil still further. Therefore even the very astringent remedies, like copper ore, vitriolic ore, and the specially cooling like hemlock, can only indurate the membranes. Even the forcible drawing together and narrowing of the pupil is injurious. For such procedures transform the affection into pupillary atrophy.

"Chap. LV.—*On Phthisis of the Pupil.* We speak of pupillary phthisis when the pupil becomes narrower and weaker.[69] This results generally from dangerous diseases of the whole body, or from violent headache. To these patients objects seem smaller, because of the narrowing of the pupil.

"The treatment of these patients must be precisely the opposite of that for mydriasis; namely, gymnastics of the upper portions of the body, of the shoulders and the hands, while the breath is being held. The head and face should be carefully massaged, then even the eyes with the tips of the fingers. The face should be affused with warm

[69] The response of the pupil to light was first discovered by the Arab, Rhazes (q. v.) in the Saracenic Middle Ages.

water, the head anointed with a slightly warming perfume, like the salve of lillies, and, a little afterward, the eyes innncted with a loosening, somewhat acrid and fluid-attracting remedy, as for example the following collyrium: ammoniated frankincense, 1 drachm; fibrous saffron, 4 drachms; saffron, 2 drachms; verdigris, 4 drachms; rub the mass up in water, make collyria, use. The eye-salve of Erasistratus is also effective. The food should be nutritious, at the same time easy to sip, the wine yellow and of a pleasant odor. A nap should be taken after meals. Baths, too, are proper, and warm affusions to the head.

"Chap. LVI.—*On Atrophy of the Eye.* We speak of ocular atrophy when, after violent headache, or in acute febrile diseases, the eyeball slowly becomes flaccid, sinks in, and, in general, is reduced in size, and to a certain degree becomes darkened, so that the vision is obstructed. This condition also results frequently after surgical incision of the scalp, and after trepannation, and such cases are absolutely incurable.

"Atrophy is, however, distinguished from phthisis in the following ways: phthisis makes only the pupil smaller, whereas atrophy produces both a diminution in size and a flaccidity of the entire ball.

"These patients are to be treated by fomentations with sponges squeezed out of warm water and by instillations of lukewarm milk, while collyria are to be refrained from. We must, however, give food which is really nourishment and which forms good humors, and thin yellow wine. Baths should be employed and warm affusions to the head, and gymnastics of the upper portions of the body while the breath is held.

"Chap. LVII.—*On Exophthalmus.* Sometimes the eyeballs are thrust forward so that they remain outside the lids. This results from an attempt at suicide by hanging and in athletic contests, or in women who strain too hard during childbirth, or even in consequence of abundant fluids which stream down from the head. For those who have got into this condition by hanging, blood should be let at the bend of the elbow. When, however, from other causes a thick exudate presses hard upon the eyes, the patient should be purged with black hellebore or with scammony. But the exophthalmia of women produced by straining in labor is brought to a cure by the purification of the female genitalia; wherefore one should seek to promote this. When, in men, after phlebotomy and purgation, the exophthalmia persists, a cupping-glass should be applied to the occiput, and the drinking of water and the taking of an abstemious diet should be prescribed. On the eye, however, one should lay a pledget of wool, to which has been applied honey and a little saffron, and on this a compress and a bandage with gentle pressure. There is needed in addition, after the beginning, affusion to the face with cold sea-water and the rubbing on of succory-juice, and of sanguinary and fleabane with opium, and the other remedies which are able to draw up and astringe.

"Chap. LVIII.—*On Synchisis.* Synchisis of the eye generally follows some violent injury to that organ, but it also accompanies extreme inflammation of the iris, when, in that affection, the vessels have burst.

The pupil undergoes a dirty discoloration, and is either enlarged or contracted. Synchisis resulting from injury should be treated by blood-letting at the elbow. Then one should fill the whole eye with the blood of a freshly killed pigeon (that of a turtle-dove is best, or, if one does not have this, then that of a domestic pigeon). Soft wool should then be soaked in an egg beaten up with wine and oil of roses should be applied and bound on. This should be repeated on the following day. On the third day fomentations and instillations of milk. Then make poultices by beating up the yolks of baked eggs with honey and powdered saffron, and spread these poultices on little pads. If, however, the pupil has already begun to purify itself, one should anoint the eye with the customary collyria for inveterate diseases, with the aromatic collyrium, and that of Apollonius, which is made of Chian wine, and others which are similar.

"Easier to cure is that kind of synchisis in which the pupil merely enlarges, keeping its natural form and color. Difficult to cure is the kind in which the pupil is distorted.

"Chap. LIX.—*Concerning Growths on the White of the Eye.* Of all the unnatural growths on the white of the eye, those which are painless, and on which little hairs often grow, as well as those which do not vary altogether from the normal color, should be treated thus: they are seized with a little hook and drawn up, then cut off with a pterygium knife; the spot is strewn with powdered salt, a compress applied, and the after-treatment carried out just as in the case of pterygium. But those growths which are reddish and nodular and supplied with enlarged blood-vessels, and are raw and cause sympathetic pains in the temples—all these should be avoided, because they are malignant, and, in case an operation is attempted, prove dangerous, causing especially prolapse of the ball.

"Chap. LX.—*On Pterygium.* One speaks of pterygium when, after decided ulceration and proliferation of the white of the eye, in consequence of psorophthalmia or inveterate ocular discharge, a delicate, tendon-like skin spreads over the eyeball. It begins to grow, generally, at the so-called greater canthus, which lies the nearer to the nose, more seldom at the other canthus, more seldom still from the region of the upper or lower lid. The pterygium in any case extends to the dark of the eye. If it becomes still larger, it reaches even to the pupil, where it disturbs the sight. Easy to cure are such pterygia as have a white color and a small base. Those of an opposite appearance are curable with difficulty. For the reddish kind are likely, after operation, to cause necrosis and hemicrania; nevertheless, after the removal of these symptoms, the eye is again well. But those pterygia which are complicated with incipient cataract, should not be treated by operation, for, when the pterygium is removed, the cataract ordinarily develops so much the faster.

"Just as little should one treat those which are thickened and rolled outward, and protrusive and indurated and complicated with sympathetic temporal pains, for these are malignant and cancerous. As to those pterygia which have encroached upon the pupil and so have interfered with the sight, their ablation, as a rule, frees the eye from

discharge, but the scar which remains in the pupillary region as a result of the operation, abrogates the vision nevertheless.

"Those pterygia should be handled surgically which have become large and so cover the dark portion of the eye. But those which are smaller and which limit themselves to the white of the eye, should be caused to shrink, when possible, by means of local remedies.

"Chap. LXI.—*Remedies for Pterygia.* For the removal of a pterygium the dry scabies remedy of copper-ore and cadmia is useful, the kind prescribed for a scabious lid-corner, and similar remedies, and the Theodotian collyrium of Severus, powdered and laid on dry, and all purifying collyria, all of which are prescribed for trachoma and fig-formation, and those which are suitable for the fly-head and staphyloma, the best being those containing wine.

"Archigenes, however, recommends for pterygium:

"Copper vitriol, 2 drachms; ammoniated rock salt, 2 drachms; gum, 1 drachm. Rub these up with vinegar, make collyria, and use. An approved remedy for pterygium, because it consumes this growth very rapidly: copper ore, roasted until it is yellow, 4 drachms; saffron, 1 drachm; use as a dry powder. Another remedy, also approved: Roasted copper vitriol, 20 drachms; Cadmia, 10 drachms; red copper-hammerings, 1 drachm; pepper, 1 drachm; use. Another, which removes pterygia root and all: roasted copper vitriol, 2 drachms; annealed copper, 1 drachm, use it dry; but after the removal of the pterygium, treat further with the collyrium made of roses or that from saffron. Another: carefully pulverize magnetite, and apply it dry once daily. Another: rub in black poplar juice with double the quantity of honey.

"Another: blue vitriol and gall from a sucking pig, equal weights. Rub up together, and use as an ointment.

"Another: burnt cuttlefish scales with ammoniated rock salt, equal parts; rub together and use.

"Another, which is also useful for sugillations and amblyopias: magnetite, 4 drachms; verdigris, 1 drachm; Sinopic red chalk, 4 drachms: ammoniated frankincense, 4 drachms; saffron, 2 drachms; honey, 5 ounces. It is also effective for leucomata.

"Another: chop up celandine, run it through a sieve, then rub it up with a little water and add ashes of the flowers of zinc, as much as it will take up, and make collyria. Use with water twice a day.

"Another: Rub up annealed copper with the urine of an innocent boy, and use.

"Another: Red copper-hammerings, red natron, pumice, white clay, each 4 drachms. Rub up with vinegar till dry, and use. Preserve it in a clean earthen vessel.

"Chap. LXII.—*The Surgery of Pterygium.* For the removal of pterygium we operate as follows: We draw the lids apart and take up the pterygium about its middle with a tiny hook, stretching it slowly away from the eye so that the epidermis of the cornea may not be detached. For, if the latter is removed with the growth, violent inflammation ensues. Then we take a needle, into which both a thread and a horse-hair have been inserted, and carry these through *beneath*

the pterygium, which is lifted up by means of the hook. Then, by means of the threads which have been passed beneath, we underbind the pterygium, and stretch it upward, very slowly drawing up the thread. We now give to an assistant the end of the thread to be held properly, seize the horse-hair with *both* hands, and, with a sliding motion, separate the growth from that which lies beneath it, beginning at the dark part of the eye and passing toward the canthus. Then we break up, still by means of the horse-hair, the attachment of the pterygium to the colored part of the eye, and holding that up taut with the thread, we remove with the bulb-pointed pterygium knife the part of the pterygium lying next the canthus, together with the root, taking care not to injure either the lids or the canthus proper. For those patients whose lids are cut together with the pterygia, suffer from adhesions. Those, however, whose canthi are entirely cut out, suffer from a running of tears. If, however, the root of the pterygium which is at the canthus be left unremoved, there follows a recurrence in case the operation is not in a position to eradicate the root with one of the remedies heretofore mentioned. It is necessary, therefore, to have a precise regard for the right amount of excision. In case, out of cowardice, the patient will not open his eye, then we lay a blunt hook beneath the upper lid, slide it gradually between lid and ball, draw up, and then operate according to the method laid down.[70]

"After the removal of the pterygium, strong brine should be dropped into the eye, then wool soaked in white of egg applied, and the eye bandaged. On the following day we loosen the bandage, foment moderately, and instil the white, delicate collyrium of Severus. On the fourth day we anoint the eye with the 'Collyrium for Eye Diseases,' and avoid, for the further treatment, the delicate and flesh-forming collyria. The 'Collyria for Eye Diseases,' however, are the nardian, the Theodotian, and all which are made of wine.

"Chap. LXIII.—*Concerning Encanthis.* One speaks of encanthis when the larger canthus, which lies to the nasal side of the eye, has proliferated. This happens chiefly in dogs. Among men those are principally attacked who live near the sea. The benignant encanthis is painless, delicate, white; the malignant variety hard, uneven, and accompanied by piercing pain.

"The benignant should be treated, the small with dry medicines such as that for scabies of the lid-corner, which is made of cadmia and copper ore, or with the following, which is the best: schistous alum, roasted vitriolic ore, blue vitriol, in equal proportions. This eradicates very satisfactorily all tumors of the caruncle. Use, however, the Theodotian remedy of Severus, rubbing it up to a dry powder, and that for fly-head, which is made of wine.

"Chap. LXIV.—*The Surgery of Encanthis.* The larger malignant encanthides should be seized with a forceps and ablated. Should, however, the prominence be entirely too large, one should pass a needle with doubled thread through the base of the tumor, then tie the thread together, and, after a brief wait, until the flesh has become

[70] Except for the addition of antisepsis and anesthesia, this method of operating has never been much improved on.

dark-blue, perform the separation with a tiny knife. Apply the remedy for psoriasis and cover with pledgets. On the following day foment, and after the third day complete the cure by means of the application of honey. Care should be used not to remove completely the substance of the caruncle along with the abnormal flesh. Otherwise epiphora ensues.

"Chap. LXV.—*On Hemorrhage from the Canthi.* Hemorrhage from the canthi occurs, especially in infants, in whom it is produced by incessant crying, the tension opening the blood vessels in the lids.

"One should treat these patients with poultices of cold vinegar-water and with cold affusions to the head; but instil egg-white both alone and also together with one of the collyria suitable for thin discharges. Further, ligation of the lower extremities should be resorted to and strongly nourishing food. In adults a wet cup should also be applied to the occiput.

"Chap. LXVI.—*On Adhesion of the Lids and Anchylosis of the Eyeballs.* The lids, when an ulcerative process has preceded, may unite with the white of the eye or with the colored portion or with each other. If, now, there results a union of the lids with the white of the eye, so that the movements of the ball are interfered with, the affection is generally called 'anchylosis'. All adhesions of the lids with each other at the temporal canthus, should be put upon the stretch with an ordinary hook, and divided, then held apart with charpie, the treatment for ordinary ulcers being introduced. But all adhesions of the free borders of the lid with the ocular membranes, should be lifted with the blind hook, while the adhesion is dissected off with the pterygium knife. Then astringe the abnormal flesh which remains behind with any kind of dry remedy, and with finely powdered copper, introduced with a sound, over the entire internal surface of the lid. The eye should be left unbandaged throughout the healing process.

"Chap. LXVII.—*Concerning Lice on the Lids.* Lice form on the eyelashes, flat, small, and in large numbers. They take their origin from the voracity of the patients, and from uncleanliness and a bad way of life.

"One should treat these patients first of all by removing the lice carefully and rinsing with lukewarm sea-water. Then apply the following remedy to the affected part: schistous alum, 2 drachms; lousewort, 1 obolus; pepper, 2 oboli: annealed copper, 1 drachm; myrrh, 2 oboli; fibrous hematite, 3 oboli; roasted vitriolic ore, 1 drachm. Powder fine and use dry. Moreover, one should bathe, and anoint the head with dispersing and strengthening remedies, and take gymnastics of the lower extremities, and proper diet.

"In a similar way the nits which appear on the lashes, should be treated.

"Chap. LXVIII.—*On Trichiasis, Distychiasis, and Phalangosis—According to Severus.* It is called trichiasis when behind the natural eye-lashes others grow forward on the lids, turn inward, pierce the membranes of the eye, and produce lacrymation. The same name of trichiasis is, however, also employed when the lids themselves are relaxed and the border of the lid turns inward, so that, as a rule, the

lashes can no longer be seen, if the lids are not stretched in a contrary sense and brought away from the ball. Physicians are accustomed to designate the relaxation of the lids by 'phalangosis,' or 'ptosis,' the rearward growing of the lashes, however, as distychiasis.

"These affections, especially distychiasis, result chiefly from a too moist condition. For, as on the earth an excess of moisture causes the grass to sprout forth abundantly, thus it is also on the lids, especially when the affluent humor is mild. For, were the afflux salty, it would be able to produce even a falling out of the natural lashes.

"The radical cure of trichiasis consists in sewing up the lids. As, however, a few patients, because of cowardice, can never bring themselves to take an operation, one ought to try to help such persons as much as possible. To this end the following remedies are recorded in the writings of the ancients.

"Chap. LXIX.—*Remedies Against the Recurrence of Extracted Hairs.* First of all remove the offending hairs, turn the lid outward and rub on fresh frog's blood, and let it dry. And the blood of the bed-bug should be used in the same way. Or, burn a white chameleon, beat up the ashes in frog's blood, and, at the time of use, moisten it with spittle, and anoint with it the place from which you have extracted the hairs.

"Another. Take the juice of the plants known as swallow-wort and fumitory; add gum in sufficient quantity; dry, and form small collyria, to be used in the prescribed manner.

"Another. Rub up the flesh of small snails with the blood of green frogs which live in a reed-bank, or with that of the land hedge-hog, add ink and let it mummify, and use it in the way mentioned, but, when so doing, spare the pupil.

"Another. Burn leeches, powder them, and use regularly, after the preliminary epilation.

"Another. Burn earthworms to ashes on a shard, make of this a fine powder, and strew it on after the preliminary epilation.

"Another. Burn a lizard in a pot, powder the ashes, add an equal quantity of gum sandarak, and use.

"Another excellent and painless remedy. Crumble the dry, but not too old, pods of carob-beans; take up the tough, scanty, honey-like fluid to be found in their cavities with the head of a sound, and, after the extraction of the hairs, stroke with this the place in question, and do it regularly.

"Another which, according to Archigenes, acts excellently. Take the gall and the blood of a land hedge-hog in equal parts, of beaver-gall a suitable quantity. Beat up the beaver-gall, finely powdered, into the blood, and make collyria like fine fish-scales. Use in this way: Extract the hairs with the roots, and then dissolve, each time, one of the little scales in saliva from the mouth of a fasting person, draw the lid down, besmear it, and hold the place fast for half an hour, till the remedy has dried on. Patients do indeed find this painful, but the hairs do not grow again.

"Another. Whip up the blood of a bat with fleabane, hemlock seed,

and cedar resin, in equal parts. Use in the manner described, without touching the eyeball.

"Another. Take a piece from the old sail of a ship, and insert it in a lamp in place of the wick. Fill the lamp with oil from an alcanna bush, collect the soot in a copper vessel, and use, tearing out the hairs and painting the spot regularly. If the hairs return, repeat the treatment.

"Another. Take the juice of the water-dock and that of artemisia in equal parts. Use.

"Another. Rub up together without water the gall of a calf and an equal quantity of beaver gall and gum. Make collyria, and, after epilation, use. Rub it in three times a day, and you will have results

"Another. Take gall and suet from a male sucking-pig, place them in a new earthen vessel, which is tight and smooth, and pour on them one-fourth glass of the sharpest vinegar and one fourth glass of oil, and underbind the vessel with a strong cloth. Let it stand seven days, pour it in a mortar, rub it up, and use it as a salve. The same thing is also good for the whole body. But the oil should be oil of almonds.

"Chap. LXX.—*Glues for Eyelashes.* Lashes which have turned abnormally inward may be glued in place. Apply mastich with the warmed spoon-end of a sound, bending back the tiny hairs into their natural position. Asphaltum is also good, and glue made from the tendons of oxen, and the slime from snails taken up with a needle, the juice from hawkweed, a solution of the so-called glues, and ammoniated incense. Also, the following compound remedy: dry succory, dry pitch, natural sulphur, asphalt, each 1 drachm; wax, ½ drachm. Melt, and take it up. When using, heat the spoon end of a sound, touch it to the medicine, and so glue up the tiny hairs.

"Chap. LXXI.—*On Sewing Up and Sewing Down—According to Leonidas.* For the sewing-up of the upper lid, the patient should be placed in a sitting position, at the left of the operator, and lower than he, and turned toward a clear light. Two experienced assistants are necessary. These should stand near, one behind the patient, facing the operator, the other at one side. Let the operator mark out for himself at the beginning with a blackish collyrium, or with superficial scratches, the proper amount of superfluous skin (which he holds up in a fold) to be excised, in order that neither too much nor too little may be taken away. For, if too wide a strip of skin is excised, the patient suffers from lagophthalmus; if, on the other hand, too narrow a piece is cut out, the lid again yields and the hairs prick the ball as before. A point in the middle of the lid, near the lid-border, is also marked with a superficial incision. After the marking, we fold the lid round, and make an undermining incision inward from the abnormal hairs, so that they direct themselves outward, toward the natural lashes. Sometimes, however, we place the undermining incision exactly at the unnatural hairs, when that is already far inward, so that the scar which finally forms prevents the former from re-growing. Nothing, however, hinders us from making *two* undermining incisions, one of them inward from the abnormal hairs for the re-position of the lid-border, the other at the abnormal hairs themselves. The undermining incision

should be rather deep, for thus it assists in the bending upward and elevation of the lid. And it ought to be carried from the one end of the lid-margin to the other. Then small, folded, three-cornered compresses should be applied, one at the greater canthus, the other near the lesser; on these compresses the assistant who stands to the temporal side and behind the patient should press with the points of his thumbs, and, at one tug, stretch the lid tight across, pressing the thumb against the lower border of the eyebrows, so that the tension of the lid may be perfectly uniform. Observe as a sign of the best stretching of the lid, that the midway marks preserve their proper places—that is, are found to be in the middle. After the stretching, one should first make superficially the inferior, straight, spear-shaped incision—so that the blood flowing down from the upper incision may not interfere with the operation. This lower incision, however, should be near the lashes. Then should be made the superior, half-moon-shaped incision. This, too, should be begun from below, from the terminus at the larger canthus, then be carried upward to the mark, and, finally, again turned downward to the lesser canthus. This incision, too, should be merely superficial, so that the muscle may not be wounded. At this point the assistant who stands at one side should stretch the lid upward. Then a small hook should be bored in at the beginning of the small piece of skin which has been cut around, in the left eye at the lesser canthus, in the right eye at the greater. Lifting the hook up now with the left hand, dissect off the piece of skin with the tiny knife for lid operations, taking care that the patient does not suffer a wound of the muscle by too deep a dissection, and so avoiding an incurable ptosis. After the excision of the skin, one should proceed to the sewing-up proper. First should be inserted the central suture, then two at each side thereof. So that the entire number of sutures comes to five. After the sewing-up, draw the lid up high, slowly, on account of the wound, and, with a suitable strip of plaster, fasten the suture-threads beneath the eyebrows; but, in the region of the incision, lay small pads with clinging and antiphlogistic medicines on them; then wool soaked in the white of egg upon the entire ocular region. Bandage.

"When, however, a strongly acrid and salty discharge causes the falling out of the natural lashes and an induration of the lid-border, while the tiny hairs which grow pathologically behind the insertion of these are caused to grow more vigorously, and the folding over of the lid of these patients offers an especial difficulty; then one should pass a needle with a firm thread through the center of the lid-margin and draw the thread up, and then with the help of a sound, turn over the lid in the customary manner, and then make the undermining incision, just as I have even now described it.

"Chap. LXXII.—*On the Sewing Down.* When the lower lid suffers from trichiasis, sewing it down is useful. First, however, a sufficient excision of the slack, superfluous skin should be marked out, just as in the former condition. For in this condition also, when too broad a strip of skin is excised, the improper condition of ectropion is apt to follow; and, if too narrow a piece, then the operation is likely to be without success. After the marking out, compresses should be laid at

the canthi, just as was described in the foregoing chapter, and, in that way, the lid placed upon the stretch on all sides. Then the assistant should press his thumb against the cheek and pull downward. In this operation the *lower* half-moon-shaped incision is made first, then the spear-shaped, or straight incision, near the lid-border. Dissect away and sew, as described, and perform the rest of the operation. Only, in the lower lid we content ourselves with the sewing down alone, and omit the undermining incision in order that ectropion of the lid may not result.

"Chap. LXXIII.—*On Ectropion—According to Demosthenes.* Ectropion of the lids is generally caused in this way, that ulceration of the inner surface precedes, together with excessive proliferation of the tissues; sometimes, however, in this way too, that the lid is drawn together by a fixed scar on its outer surface, and so is turned outward. The disease attacks the under lid more frequently. One should treat the rather pronounced proliferations with the following dry remedy: annealed copper, 1 drachm; copper vitriol, 1 drachm; roasted vitriolic ore, 1 drachm; roasted copper ore, 1 drachm. Another. Annealed copper, 8 drachms; roasted vitriolic ore, 2 drachms; roasted copper ore, 1 drachm; copper vitriol, 1 drachm. Another, for ectropia which have already become inveterate. Verdigris which has been roasted on a potsherd and finely powdered; apply either alone or with an equal quantity of white lead.

"Chap. LXXIV.—*The Operation for Ectropion—According to Antyllus.* The larger proliferations should be removed with the knife, then annealed copper, powdered, should be applied, or aloes with manna, and, on the following day, after fomentation, the treatment should be repeated. On the third day, after fomentation, apply honey, and continue so to do till healing is complete. When, however, the ectropion is very large, the following operation should be performed. From the inner surface of the lid one should bring forward two incisions, which present the form of a lambda [Λ], so that the narrow end of the lambda looks downward, toward the cheek, the broad end upward toward the lashes; then one should excise the lambda-shaped strip, and with it the flesh which lies beneath. For the underlid has a cartilage. But the skin should be left undivided. Next, unite the lips of the incision with a suture. One suture will suffice, if placed up close to the lashes. Thus curved and bunched together, the lid is turned inward.

"When, however, a scar, which, from any sort of cause, had formed on the external surface of the lid, turns the lid outward, then one should, in the way described, remove from the inner surface of the lid the lambda-shaped strip, but not make the incisions very deep, and bring the lips of the wound together by means of a suture, as mentioned. Then, from without and by means of a blunt hook, we put the scar upon the stretch and thrust a needle with a double thread beneath the fleshy structure of the entire scar, beginning at the lesser canthus and carrying the needle clear through to the greater. Then, while the needle holds, we loop the thread beneath both its ends, and by means of these draw the entire fleshy structure of the scar upward and so

complete the excision of the latter, taking away together with the fleshy growth, also the perforating needles. After the operation, we fill the loss of substance in the skin with lint, lay on a compress which has been dipped in water and a bandage over that. Till the third day we keep the bandage moist with cold water and let the compress lie. On the third day we unbandage, and wash with a sponge which has been dipped in lukewarm water. Fomentation is unnecessary in these cases. Care must be taken lest the covering over of the internal loss of substance go amiss. When, however, the threads have come away, after the beginning of firm union; then one may, without anxiety, apply fomentations continuously, in order to make the scar more delicate and to pacify the eye. Then the inner surface of the lid should be anointed with astringent remedies. But the outer loss of substance, that in the skin, should be held apart during the entire treatment, by the employment of a relaxing remedy. For, in the growth of the external skin, lies a certain foundation for the inward-turning of the lid. When, however, ectropion is caused by the growth of an epicanthus then, after extirpation of the tumor, the lid returns to its normal situation. One should know that ectropion of the upper lid is incurable; also that this condition in the lower lid is not to be improved, when it has been caused by paralysis. The same is true also of an ectropion produced by the excision of too broad a piece of skin, especially in the operation of sewing-down, and of the ectropion caused by a very broad scar in the skin, of course in consequence of ulceration, for example in the case of carbuncle.

"Chap. LXXV.—*On Lagophthalmos—According to Demosthenes.* Those are called hare-eyes [lagophthalmoi] whose upper lid is drawn high, and whose lids stay open during sleep, as is the case with hares. The disease arises sometimes in conequence of an anarrhaphy, whereby the lid is elevated more than necessary, so that it cannot cover the eye; sometimes, after a spontaneous ulceration in the skin, for example, carbuncle. One should treat these patients by making a half-moon-shaped incision round the entire scar so that the convexity of the incision looks upward, the horns, however, downward, toward the border of the lid: and then by forcing the incision to gap by means of lint, drawing the lid downward and trying to bring it into the natural position. As to lid contractures, one should place the incision at the point to which the lid has been drawn, and cause the lid, in a similar way, to yield. In the treatment, drying remedies should be avoided, such as honey-mead; but employ in solution the tetrapharmikon and irrigate these eyes with goatshorn juice, and employ for these patients solely the altogether relaxing and anointing treatment.

"Chap. LXXVI.—*On Sclerophthalmia—According to Demosthenes.* Sclerophthalmia exists when the lids become hard and the eyeball itself harder and scarcely movable, painful and reddened, and especially when, after the patient arises from sleep, the lids are separated with difficulty, and no liquid secretion is discharged, but tiny scales form in the corners of the eyes, which seem to be dry and baked together, and when, if we try to evert the lids, we find it difficult to do this, because of the induration.

"Chap. LXXVII.—*On Sclerophthalmia.* Sclerophthalmia exists when the eye is dry, itches and is tolerably painful, but without induration.

"Chap. LXXVIII.—*On Psorophthalmia.* Psorophthalmia exists when the corners of the lids are ulcerous, red and very itching, and the lids are red, while salty or corrosive tears are discharged.

"Chap. LXXIX.—*Treatment of Xerophthalmia, Sclerophthalmia, and Psorophthalmia.* These three diseases should be treated carefully. If neglected they are productive of cataract and glaucoma and chronic ophthalmia, ulcers and staphylomata.

"Xerophthalmia should be treated (aside from the care of the whole body) with such remedies as attract fluid to the eyes, as for example the dry remedies yet to be described and the so-called soldiers' remedy, and the diacentetic collyrium and the like. Sclerophthalmia we should likewise try to heal by medicines which are able to extract fluids, anointing the eyes with the fluid remedy of Erasistratus and the like. We must also use the softening and moistening remedies, such as irrigation with materials which are warm, and according to its mixture mild, and also employ sponge fomentations regularly. But for these patients we should avoid the cooling, obstructing, and uniting remedies, such as irrigation with cool fluid. For, by such things the eye is only made harder. If, however, psorophthalmia and sclerophthalmia co-exist (that is to say, the lids as a rule indurate from the acridity of the secretions, so that the canthi are corroded and ulcerous, while the eye and lids are movable with difficulty and hard) then one must foment the eyes at first with sponges, then touch the canthi, at first with the dry psoriasis powder, then letting a moderate time go by, foment again with the sponge, and finally anoint the eye with a remedy which is able to abstract fluid, such as the fluid remedy of Erasistratus, the soldier collyrium, and the diacentetic. The composition of the dry remedy for scabious lid corners is as follows: raw copper ore, 5 drachms; cadmia, 5 drachms. This is powdered in a pipkin, which is then covered with a lid, smeared with plaster, and set in a vessel containing thin vinegar, so that the pipkin, though wetted externally, still cannot be penetrated by the fluid. It should be left so for seven days. Then the mass is dried in the sun and powdered. Another remedy, the dry one of Philoxenus, called 'Ingratitude,' and good for excoriated canthi, scabious conditions and sclerophthalmias: cadmia, 2 drachms; raw copper ore, 1 drachm; aloes, 2 oboli; verdigris, 2 oboli; pepper, 10 grains; rose blossoms, 2 drachms; use as a powder. Another for scabious ophthalmia: cadmia, 1 drachm; annealed copper, 1 drachm; spikenard, 1 drachm; roasted pepper, 2 oboli; rub up in the sun with vinegar, dry it, and use as an important remedy. Another for corroded canthi, that of Menocles, for lachrymation: metal ashes, 4 drachms; juice of unripe grapes, dried, 2 drachms; spikenard, 3 oboli; roasted pepper, 15 grains; use in powder form. Another: cadmia, 2 ounces; ammoniated rock-salt, 2 ounces; betel-leaves, 2 ounces; pepper, 1 ounce. Use. Another, which is useful for lachrymation: spearmint, 3 ounces; copper, 2 ounces; soot of cedar resin, 1 ounce. Use. Another for psorophthalmia, fig-formation, suppuration ulcer, and fleshy pro-

liferations: Cadmia, 3 drachms; copper ore, 20 drachms; pepper, 50 grains; Celtic nard, 1 drachm; rub up the cadmia and copper ore with wine, and, when it has become dry, add the nard and the pepper as powder; make of this a fine down, and use. The remedy of Capito for psorophthalmia and excoriated canthi, discharging eyes and condylomatous lids: We take cadmia and break it into pieces of the size of barley grains. Then we knead these together with Attic honey, lay them in an earthen vessel, and cover with a lid containing a hole, and smear the lid-joint with clay, and set the vessel upright among glowing coals, and blow these into flames. When, however, the rising steam has become whitish, then we take out the vessel, remove the lid and quench the cadmia with old wine. We then put 8 drachms of it in a mortar, adding 8 drachms of annealed copper, 4 drachms of antimony, and in case it can be had, also 8 drachms of the blue carbonate of copper; pound it, pass it through a sieve, rub it up with wine to a collyrium, dry it, take it up, and use it by painting the lids with it on the head of a sound mornings and evenings. I, however, have kneaded up the cadmia and all the other useful things with serpent fat and roasted it, then extinguished it with wine, dried it, and used it as a powder. Another. Genuine locks of purple wool, 8 drachms; cadmia, 20 drachms; annealed copper, 10 drachms; hematite, 10 drachms; all powdered and kneaded with honey, and toasted as described, and extinguished, and rubbed up with wine and dried, and so used. Another, that of Archigenes, for all the affections under consideration. Rub up with honey the boiled lees of olive oil, and use. Use also the collyria and dry remedies which I am yet to describe in the section on usual remedies.

"Chap. LXXX.—*On Madarosis, Ptilosis and Milphosis.* Madarosis and ptilosis are diseases of the lid-borders. Madarosis consists simply and solely of the falling out of the eye-lashes, caused by acrid discharge. In the so-called ptilosis the affected parts are also thickened and calloused, so that the disease is compounded of madarosis and sclerophthalmia; and even the remedies for ptilosis are similar to those employed for the two conditions already described. A dry remedy, however, is best for this disease, that of Philoxenus for itching and excoriated canthi; it is useful moreover for amblyopia: cadmia, 8 drachms; ammoniacal rock-salt, 2 drachms; saffron, 2 drachms; spikenard, 2 drachms; white pepper, 1 drachm; use as a powder. Another, which is a lid-paint for women, effective for excoriated canthi and ptilosis of the lids: antimony, roasted and quenched with woman's milk, 13 drachms; aloes, myrrh, spikenard, 2 drachms; roasted barley grains, finely ground, 4 drachms; use it as a dry powder. Another for ptilosis of the lids and marginal lid-ulcers: oxfoot marrow from the right forefoot, rub it up with soot, and use. The soot, however, should have been prepared in advance in this way: Draw a piece of paper into a lamp as wick, fill it with sesame oil, light it, and hold above it a flat earthen or metal pan. Catch the soot, and fan it together with a goosewing used for dusting, and rub it up with the marrow and use. Another: The curded milk from the stomach of a calf, when rubbed on, acts excellently. Another, that of Sasandros, for

red milphosis and chronic conditions; it is useful also for encanthis: cadmia. antimony, raw copper ore, raw vitriolic ore, each 8 drachms; pound it fine, knead it up with honey, and roast it, as already described; then extinguish it with wine, and, after pulverizing, add spikenard, 2 drachms; roasted saffron, 2 drachms; pepper, 1 drachm; rub it all together, and use. There are also simple remedies which are effective for ptilosis and marginal ulcers of the lids, namely, boiled lees of olive oil, catechu, mountain blue, which is used by painters. For, rubbed in with water, this destroys the morbid humors of the part. and promotes the growth of natural hairs. Iron rust, rubbed up for many days in the sun with wine and myrrh and formed into a collyrium. Metallic ashes, taken up with onion juice.

"Chap. LXXXI.—*On the Abscess in the Eyes—According to Demosthenes.* Abscesses of the lids should be treated in this way: Those which point toward the inner surface of the lid by cutting off their points and squeezing out their fluid. Then instil brine, apply wool soaked in the white of egg, and bandage. On the following day foment and anoint with honey, and, for the rest, instil the astringent collyria. As to those which point outward, one should, after dividing the skin and evacuating the pus, apply grated linen with honey and wool, and then a bandage.

"As to those abscesses which have caused caries of the lid-cartilage, one may, if the abscess forms outwardly, purify with egg and honey, and again form flesh with the dry remedy for fractures of the skull. When the abscess is internal, we have to evert the lid and shave off the denuded portion of the cartilage all around, and apply the finest copper powder, and also lay on the outer surface of the lid an egg beaten up with wine and oil of roses. On the following day foment, apply the finest copper powder, and lay on the external surface the white of an egg. On the third day honey should be stroked under the lid, and the astringent collyrium be used.

"Chap. LXXXII.—*On Lithiasis in the Lids.* We speak of lid-lithiasis when, after eversion of the lids, these tophus-like formations are seen, of a whitish color and a raw condition, and resembling pimples in form. This condition should be treated by everting the lid, and dividing the membrane at the apex of the formation, then with the spoon of the ear-sound scrape out the tumor which seems as if cast in a mould. Then should be applied annealed copper powder, and wool, soaked with the white of egg, together with wine and oil of roses. and, finally, a bandage. The following day the treatment should be repeated, after a fomentation, while, on the third day, honey should be rubbed in. For the tiny stones which grow on the outer surface of the lid, one should apply, after dividing the surface and scraping out the stone, a little pad smeared with tetrapharmicon plaster.

"Chap. LXXXIII.—*On Chalazia.* The lids are said to be affected with chalazia, when, after their eversion, certain roundish, transparent elevations are visible, which are similar to a hailstone, and from which, when they are cut open, there runs a fluid resembling the white of egg.

"These formations are treated by everting the lids, scraping out the chalazia with the scalpel, and evacuating the fluid, then rubbing in

the following dry remedy: annealed copper, 2 drachms; metallic hammerings, 1 drachm; sandarak, 1 drachm; verdigris, ammoniacal rock-salt, each 3 drachms; saffron, 3 drachms; myrrh, 2 oboli. Use as a powder.

"Sometimes there also arise, on the external surface of the lid, hardish chalazia, similar to beans. If you squeeze one of these, you cause the patient violent pain, occassionally even syncope. One should treat such chalazia by dividing the skin over the apex, and curetting with the spoon of the ear-sound. The patient, as a rule, recovers promptly, merely from the application of charpie and honey and from fomentation.

"If, however, one would treat chalazia only with medicines, one should use the following: boil the fruits of the wild fig-tree and apply them, or else the leaves of the fig-tree. Another excellent salve: wheat meal, 3 ounces; natural sulphur, 1 ounce; rub up with water, form into discs, and use. Effective also are the prescriptions for styes.

"Chap. LXXXIV.—*On the Crithe or Posthias.* 'Crithe' or 'posthias,' is the name given to the condition in which, on the outer surface of the lids and near the lashes, a small abscess arises, similar in form to a grain of barley. It is easily cured by fomentation with the warmed head of a sound. It is also readily dissipated by fomentations with warm white wax. Or tear the head off a fly, and rub with the rest of its body the diseased part. Or soften some resin galbanum, add a little natron, and apply. Or knead into well-worked wax a little raw vitriolic ore, and apply that. Effective also are dried figs, boiled with wine of honey and rubbed up with a little galbanum. Or rub up gum sagapen with vinegar, and apply with friction. That is useful too for chalazia. The place should also be fomented with a sponge and hot bread crumbs. After the evacuation of the fluid, one should anoint with honey, then with the collyria which are used for ulcers.

"Chap. LXXXV.—*On Ganglia, Atheromata, Steatomata and Melikerida on the Lids.* In some persons these affections also form on the outer surface of the lids. Ganglia are treated with wax ointment, and with those plasters which I am still to point out for ganglia, as well as by rinsing with warm water. The ganglion is a circumscribed swelling of a tendon. But melikerida, the small steatomata and atheromata are occasionally treated by the application of a caustic to the apex of the swelling until the skin which covers it has sloughed, and then after the falling away of the escar, by curettment of the membrane which surrounds the liquid contents by means of the spoon of the ear-pick. If this membrane cannot be removed it should be sloughed out by the following caustic application: sandarak, 2 drachms; arsenic, 1 drachm; copper hammerings, 1 drachm; black hellebore, 1 drachm; wild cucumber, 2 drachms; paper reduced to ashes, 2 drachms. Use with oil of roses.

"But the very large growths are to be treated by operation, like those in the rest of the body, taking them away by the root together with the membrane which surrounds the accumulation. The lips of the wound should then be brought together by sutures, and the after-treatment be like that for an anarrhaphy. Care should be taken,

however, not to remove too broad a strip of skin at the operation, lest lagophthalmus follow.

"Chap. LXXXVI.—*On Varicose Tumors and Other Malignant Growths on the Lids.* Varicose tumors of the lids should not be operated on, because they are malignant. By no means such growths as are rough, painful, and red, and yield to pressure by the finger. For these also are malignant and incurable.

"Chap. LXXXVII.—*On Ægilops—According to Severus.* Ægilops is an abscess which forms near the larger canthus. The trouble is curable with difficulty, since, because of the thinness of the parts affected, the bone which lies beneath, becomes carious. Because of its close juxtaposition, it sometimes causes the eye itself to be lost, by way of the natural, tiny perforation at the canthus [punctum lacrimale].

"When the violent inflammation ceases, one should immediately, on the first of the days, endeavor to drive this back, merely by rubbing the inflamed spot with the Antoninian collyrium, or with some other of the strongly repressive and anodyne. For this inunction, as a rule, dissipates the accumulation. If, however, the condition of violent inflammation still persists, one should seek to treat it, like the other violent inflammations, with all those dispersive medicines which are effective without irritation. For, on the one hand, the eyeball is drawn into sympathy by the employment of acrid medicines, and, on the other hand, the suffering part itself is brought to a greater degree of inflammation. I myself, however, am accustomed, for those inflammations which have not passed over into suppuration, to employ the Barbarian Plaster, or that called the Lioness or Athene, or the Willow, or the Vinegar-Oil-Plaster, and in that way to disperse and dry up the abscess. Asclepiades, however, has prescribed the following medicines for ægilops: Of the juice of the water crowfoot, which a few call also wild portulacca or small house-leek, of the juice of nightshade, each 6 ounces; frankincense, 8 drachms; resin galbanum, 6 ounces; mastich, 3 ounces; boil it, after pulverizing the frankincense; add the mastich at once, the already-kneaded resin galbanum, however, not until the mass has become fluid. Another: frankincense, 8 drachms; myrrh, 6 drachms; pine tree resin, 1 drachm; wax, 8 drachms; schistous alum, 4 drachms; natron foam, 4 drachms; hare's runnet, 4 drachms. Powder this, and knead it with the precipitate from the salve of lillies.

"If, however, the dispersing medicines remain without effect, and the inflammation will pass into suppuration; then we must cut the part open at once, evacuate the matter, and employ the following prescription: bdellium-resin, myrrh, pine-tree resin, natron foam, colophonium, each 4 drachms; wax, 10 drachms; ointment of lillies, as much as necessary. Others take, in place of the colophonium remedy, pulverized leaves of the olive tree with fat, and make of these poultices for the ægilops. Filth from the armpit of a sheep, with ordinary fat, may be used in like manner. Or macerate the roots of black hellebore, and apply them. Or make poultices of pellitory of the wall. Or pea-meal with honey, or knead the ashes of grape-vines with vinegar and lay that on. Lousewort and ammoniacal frankincense

may be applied with honey, or schistous alum with turpentine, applied in the form of pledgets.

"When, however, it draws near the canthus, but does not press forward against the outer skin: then one should open with the lancet or with the pterygium knife the central part of the canthus, and cause sound flesh to grow from out of the depths, but afterwards dessicate the growing flesh itself. That happens when we use no fatty substances at all upon the part. For this reason, we should, at the beginning, after the opening, employ boiled lentil meal, or pomegranate peel with honey.

"When, however, the place is purified, and the flesh is already growing, we strew on finely powdered glass foam, and continue to do so till healing is complete. Wonderful is this remedy, and, in addition to its instantaneous effect, it is also approved by theory. Schistous alum, too, finely powdered and beaten up with a little turpentine, to the consistency of plaster, purifies, creates flesh, and cicatrizes with certainty. One should, however, get some of the medicine into the cavity of the ulcer and apply externally a tiny pledget which is covered with it.

"By using this treatment, I have not been compelled to employ any other remedy for recent ægilops. But the remedies pointed out by the ancients for this affection are the following: To cure ægilops, in case there is as yet in the depths no carious bone: camomile leaves chewed and laid on. Or mallow leaves, chewed and applied with salt. But, after opening the abscess, use the mallow leaves alone as a powder till cicatrization has occurred. Or chew up ordinary nightshade and the narcotic nightshade, or myrtle, and lay on. Also the foliage of the virgin's bower, or of leadwort, or the juice of the wild oats which grows amid other grain, acts effectively, laid on with wheaten meal. Leaves of the sheep's tongue chewed and applied. Frankincense and the dung of pigeons are mixed and applied, and this becomes hard and clings till cicatrization has occurred. Another. Hive-dross, turpentine, and frankincense, in equal parts; make a compress, and use. Effective too is a strewing-powder of pea-meal and honey. Dry the gall of a sucking-pig over smoke, rub it up, and apply it to an ulcerating ægilops. Another. Rub up frankincense, beat it up in liquid pitch, make of it a plaster, apply. This causes a commencing ægilops to disappear, and one which has broken to heal, if it is introduced into the ulcer as well as laid upon it. A tested remedy for ægilops and scrofula: Rub up fresh lily roots to the consistency of plaster, for it comes to this consistency by being rubbed; and, when laid on, it brings the disease to maturation, cleanses it, and cicatrizes it to the end.

"Chap. LXXXVIII.—*On the Burning of Ægilops.* For those patients in whom the disease has become chronic and the bone carious, or toward the canthus a fistula has formed, while the outer skin has cicatrized, we make a three-cornered excision of the flesh which lies above the part, making the point of the excision adjoin the canthus; for we lay a sponge on the eye and set a glowing iron in the cut-out place and burn to the bone, in order to cause an eschar from the bone to be cast off. We also burn the side-parts in the cavity of the ulcer,

and especially the upper wall. For, if one observes with care, after the employment of the first cautery, he sees indeed a very tiny perforation, which is conducting from within obliquely to the ulcer fluid which looks like a tear. For this reason the cautery iron should be held tight against the little perforation. When we have cauterized sufficiently, we employ boiled bean-meal with honey. But when the eschar has come away, and the ulcer is to a certain extent purified, then we pulverize fibrous alum and beat it up with a little liquid turpentine, till it reaches the consistency of salve, then introduce it into the cavity of the ulcer, and prepare a compress of it, which we lay upon the outside of the ulcer. For that, as a rule, brings about healing and cicatrization most speedily. The strewing on of the finest powdered glass, also, as a rule, makes flesh very beautifully. Try it, it has been tested.

"Chap. LXXXIX.—*On Anchylops.* On the above-mentioned spot where ægilops arises, there forms an indolent accumulation of the thickness of virgin honey or a gruel-like condition, generally surrounded by a circumscribing membrane, painless and gradually enlarging. It is treated by means of an operation, just like atheromata anywhere else in the body, the skin being incised and dissected away and the circumscribing membrane being radically removed. After the removal of this, we are accustomed, for greater security in the treatment, in order that there may not be a recurrence of the trouble, to cauterize the place with a hot iron. Afterwards, we treat with bean-meal mingled with honey. When, however, the eschar has come away, we use, as already mentioned, alum and turpentine till cicatrization is complete.

"Chap. XC.—*On Discharging Eyes.* 'Running eyes' is the name of a condition, in which, as a result of the formation of an ulcer, or the radical removal of a pterygium, or of an encanthis, the entire inner canthus is taken away, so that it can no longer remove the affluent tears which then rather flow down the cheeks. It also results occasionally from the mistreatment of ægilops. 'Weepers,' however, are called those which, because of an inveterate discharge from the eyes, are always swimming in tears. One should treat those patients whose canthi have been radically exsected by the application of a remedy which is in condition to thicken the place and to make it firm, for example the so-called ash-remedy. In case, however, a callosity should form, one should first irritate with a more acrid remedy. One should also treat this trouble by operation. Place a handkerchief round the neck of the patient. Tighten it, and the veins on the nose stand out. Divide the veins with a triangular knife. Then lay a damp sponge round about the eye, and press the cautery to the spot, not as far as the bone but merely singeing the skin and the place of division. The cautery-iron, however, should be three-cornered. Then use bean-meal and honey. When, however, the ulcers have become clean, let the eye stay open till the canthus has filled with clean flesh, in order that adhesions may not result. Alum mixed with turpentine is also good for this purpose.

"But eyes which are moist or weeping from chronic ophthalmia

should be treated, before everything, by persistent water-drinking and restriction of food and by gymnastics, promenades, massage and shearing of the head, and cold affusions to it, and by a way of life which tends toward health and the production of thick humors. To the eye, however, one should apply obstructing, cooling, and astringent remedies."

So much for the ophthalmology of Aëtius of Amida—which, as we stated at the beginning, is, in effect, a clear and consecutive account of the entire ophthalmic materia medica, therapeutics, pathology, prognosis, and even the most of the ophthalmic surgery of ancient times. Taken together with the ocular anatomy and physiology of Galen, as well as with that author's optics, it furnishes a résumé of the ophthalmology of antiquity. If anything be lacking, it is solely in the matter of surgery which, in Aëtius, is just a little slighted. To counterbalance this, however, we have the ophthalmology of Paulus of Ægina, which is exceedingly rich in surgical detail, and which was written, or, rather, extracted and compiled, about one century later. But of this again.

Next after Aëtius of Amida came Alexander Tralles, who, though a great physician in general, was, as regards our special field of work, almost a non-entity. Born at Tralles, Lydia, in 525, a son and the brother of physicians, he studied in numerous countries, settling at last in Rome, where he lived until his death. Some years before his passing, he composed an immortal work, "*Twelve Books on Medicines.*" The ophthalmic part of the volume consists of but little more than a collection of prescriptions, and we here have mentioned Alexander merely because he was the only man who seems to have written at all on ophthalmology between the time of Aëtius and that of Paulus of Ægina.

Paul of Ægina was a famous surgeon, obstetrician, and ophthalmologist, whose life dates are not precisely known but who flourished in the last three quarters of the seventh century. His dates, as given by Baas, are 625-690. Studying at Alexandria, he practised in that city for a long time, and would seem to have prospered greatly. He must have had the freest access to that enormous repository of learning, the Alexandrian library, whose medical collections were condensed and, as it were, safely set aside by him in the very nick of time—i. e., just before the destruction of the Alexandrian museum, or library, by the great Mohammedan general, Amrou.

And here we shall have to remind ourselves for a moment of the great events occurring just outside the field of ophthalmology.

In the desert depths of Arabia arose (about 630 A. D.) and thence passed into the affairs of the formerly civilized world a strange and unexpected force. A man by the name of Mahomet, believing himself to be a prophet of the one everlasting God, so drew to himself the minds of his countrymen that, within a century, this ebony Arab, and, after him, his lieutenants and successors, had overrun not merely the deserts and oases of Arabia, but an immense district which, though not conterminous with the mighty Roman Empire in the heydey of its power, was little less extensive. Persia, Syria, Egypt, all North Africa, and Spain successively fell beneath the dominion of the Arab. These dusky warriors, though now far from their native deserts, even appeared upon the point of overrunning Gaul, Germany, Italy, England, in fact the whole of Europe, when the great tide of invasion was rolled back by the genius and energy of one man—Charles Martel. This leader and his men, at the battle of Tours, slew, it is said, three hundred and seventy-five thousand Arabs, with a loss of only fifteen thousand Christians. As a result of this battle, even Italy and Rome were spared. Forty-six years, however, after the flight of Mohammed from Mecca (the famous "Hegira" from which all Mohammedans even to this very day are accustomed to reckon their time) the Arabs were besieging the capital of the Eastern Empire—Constantinople—though, on this occasion, without success. In 716 A. D. they laid a second siege, this time for two years, again, however, unsuccessfully. Nevertheless, long centuries afterward, the Turks, who had become Mohammedans, laid siege, under Mohammed II, and captured the great capital of the only remaining half of the Roman Empire; and that city is today Mohammedan, albeit Turkish, and not Arabian. This occurrence, however, was near the close of the Middle Ages. Now let us return, and view the effects of the wild Arabian invasion of the Roman world—an irruption of desert tribes who knew but little about science, and who thought the only necessary book in all the world was the Koran—on science in general and on medicine in particular.

The Arabs, at first, did not take kindly to western culture. This is rather peculiar, in view of the fact that, before Mohammedan times, the learning of the Roman Empire had already penetrated to the more important centers of Arabia. It seems, however, as if the introduction of the Mohammedan religion had caused the Arabs to forget the little which they had learned of real art and real science from their more intellectual neighbors. At all events, when the Saracens, conquering Egypt, entered the city of Alexandria, they burned, as we

have stated, the famous library at that place, thus creating a gap between the ancient and the modern era which can never be completely bridged. Just before the burning, the Arab general, Amrou, is said to have inquired casually of the calif, Omar, as to what should be done with all those books. The reply was characteristic: "If these writings of the Greeks agree with the book of God [i. e., the Koran] they are useless and need not be preserved: if they disagree, they are pernicious and ought to be destroyed." And so the books were destroyed—those priceless intellectual treasures of antiquity. They were used, in fact, for the purpose of heating the water in the public baths of Alexandria—almost 4,000 in number—and so numerous were the manuscripts that they lasted, even when so dealt with, for more than six continuous months.

Now, how did it happen that these vandal-like Arabs, after their work of destruction at Alexandria, come to alter their unmelodious tune, and, from being destroyers, to devèlop into preservers of the learning of antiquity? The story is a long one—too long for re-recital in this place. Suffice it that, sooner or later, the Arabs became almost the only friends of learning upon this planet: as if to make amends for the terrible mistake at Alexandria, they cherished and preserved the light of natural science, till the Western World—which now seemed wholly indifferent to matters intellectual—should be ready to assume the rôle of bearer of the torch once more, and to replenish it, so to speak, with new and better oil.

To return to Paulus of Ægina. His great compendium of medicine, of which we have already spoken, and which, as we have said, contains the sum and substance of the medicine, special and general, of Alexandria, consisted of seven books, called "*Hypomnema.*" It at once became a high authority, and so remained not merely throughout the Byzantine Middle Ages, but also through the whole of the Saracenic, or Arabian period—of which we soon shall speak. The Arabs, in fact, called the work, "*The Collection of the Pleiades,*" in allusion, of course, to the seven books of which it is composed, and also to their brilliant and permanent character.

The parts of the great "*Hypomnema*" which deal with ophthalmology are: Book I, Section 21, "On Dimness of Sight;" Book III, Section 22, "On Diseases of the Eye;" Book VI (Surgical), Section 2, "On Burning of the Head for Ophthalmia" and Sections 4 to 22 inclusive, which treat of nearly all the other surgery of the eye as this was known and practised in the seventh century A. D.

Since all these parts, in English translation, will be given in this *Encyclopedia*, beneath the rubric, **Paulus of Ægina,** we need not

here discuss them further than to say, that only in the surgical portions of his work is Paulus at all in advance of Aëtius of Amida, and that, even in those portions, his only, or at least his chief, superiority is in matters of mere detail.

After Paulus of Ægina the next great Byzantine was Leo, who flourished a little before the middle of the ninth century. He wrote for a young physician, George by name, a so-called "*Medical Synopsis,*" a section of which is devoted to diseases of the eye. Though a prominent Iatrcsophist, or professor in what remained of the medical college at Alexandria, it would seem that Leo was not very prominent in the special field of ophthalmology.

In the following century—i. e., the tenth—there appeared another Byzantine physician of a slight importance in ophthalmology—Theophanes Nonnus. At the command of the Emperor, Constantinus Porphyrogeneta, he compiled from the writings of Oribasius, Aëtius, Alexander, and Paulus a book entitled "*Epitome of the Whole Art of Medicine.*" The work is rich in the field of materia medica, poor, however, in pathology and surgery. A number of chapters, of no particular importance, are devoted to the ophthalmic materia medica.

Then came the last of the Byzantines—Johannes Actuarius, who flourished in the fourteenth century. A Christian physician and philosopher, the son of a certain Zachariah, he became the court-physician, or "actuarius," at the court of the Paleologi. He was also the author of a number of valuable medical works. Of these the most important are, "*Materia Medica*" and "*Therapeutics.*" In the first-named work there is some ophthalmic matter, but none of very great value.

And so we have come to the end of the Byzantines—the mediæval remnant, or continuation, of Greek, and Greco-Roman medicine. And what a sorry showing! To Aëtius of Amida and Paulus of Ægina we are greatly indebted—for what? For the preservation in their works of the works of certain of their mighty predecessors. That is all. As to Alexander Tralles, Leo, Theophanes Nonnus, and Johannes Actuarius, it is, with respect to all of them, almost a case of "thank you for nothing." These four men, in fact, have here been mentioned merely as a matter of preserving the continuity of this history. "To such base uses may we come, Horatio!"

B.—THE SARACENIC MIDDLE AGES.

After the fitful flickering and final fizzling out of the Byzantines, it is really a pleasure to turn to the Arabians, the great preservers of

the knowledge of ancient times, to which in fact they made some very original and valuable contributions.

Before we proceed, however, to the Saracenic ophthalmology, we ought to recall the fact that in the sciences more or less collateral to medicine—mathematics, chemistry, and pharmacy—the Saracens made great progress. Take, for the best example, chemistry. Although the name itself is derived from the indigenous name for the land of Egypt —*Chema*, or black, in allusion to the color of Egyptian soil—yet so little had real advance been made in chemistry to the time of the Arabs, that the strongest acid known before the Arabic era was vinegar. An Arab by the name of Geber,[71] who lived near the close of the eighth century, discovered nitric and muriatic acids, and invented the so-called *aqua regia*—by the simple process of adding a little sal ammoniac to the nitric acid. Thus he became the first of human kind to dissolve gold—literally. Numerous other advances were made by Geber. For example, the processes of filtration, distillation, calcination, and sublimation were by Geber introduced into chemical science. Geber manufactured sal ammoniac, carbonate of soda, alum, saltpeter, and green vitriol, alcohol (from wine), nitrate of silver and bichloride of mercury. He wrote one whole excellent work on the single subject of chemical apparatus. A pretty good list (and not exhaustive either) of things accomplished by this one Arab (if one he truly were) in the field of natural science.[72]

Turning to Arabian ophthalmologists, the first we have to consider is Halaf at-Tulmi. Once a slave, this gifted Egypto-Mohammedan became a celebrated physician and skilful operator on the eye. He is, in fact, of considerable importance in a connected history of ophthalmology, because the first Mohammedan to compose a text-book on diseases of the eye. The title of the work (the writing of which consumed the years from 877-914) was "*Book of the Final Aim and Sufficiency concerning the Structure of the Two Eyes and Their Condition and Their Treatment and Their Medicines.*" Though of very great value in its day, the volume is not now extant.

Next in order of time comes the immortal Rhazes, discoverer of the pupillary reaction to light. His full name seems to have been Mohammed ibn Zakarijah Abu Bekr Ar-Razi, and he is also called Ar-Rasi,

[71] It is thought by modern writers that "Geber" was really a kind of collective appellation, whereby were named not one but a number of Saracenic chemists—just as, for example, the name, Hippocrates, was frequently signed in antiquity to numerous books, or writings, which were certainly composed by a number of other authors than the Father of our profession.

[72] To the Arabs we are also indebted for alkermes, camphor, cassia, julep, manna, musk, nutmeg, rhubarb, senna, sugar and syrup.

Peace and gratitude to their dusky ashes!

El Razi, Er Razi, Abubater, Abubertus, Abubeter, and Bubikir. He was born at Rai (hence the names, Rhazes, Ar-Razi, Arrasi, El Razi, etc.) A. D. 850. He became at first a cithern-player, later a philosopher, physician, court physician, medical teacher and author. His medical education was received at Bagdad, where too he became a director of the hospital as well as a professor in the medical college. In his prime he was one of the most widely known and highly honored of physicians, and patients came seeking his services from the farthest portions of the civilized world. He was a true disciple of Hippocrates, being a careful observer and continuous reasoner. In his old age he fell on evil days, and died, totally blind and in abject poverty, A. D. 932.

Ar-Razi, or Rhazes, is chiefly remembered by general practitioners for his little book, "*De Variolis et Morbilis*" (On Smallpox and Measles), which is truly the earliest monograph on, but not exactly "the earliest mention of," smallpox, in all the annals of medicine. However, Rhazes's *magnum opus* is "*Al-Hawi*," or "*Continens*" ("The Content"—i. e., of medicine). This encyclopedic affair does really meet the exactions of its ambitious title. The second book of the work it is that concerns the ophthalmologist. This book, indeed, takes up almost, but not quite, every phase of mediæval oculistic science. Here, however, we will not exhibit Rhazes's ophthalmology, because, in its essence, it is very much the same as that of Ali ben Isa, which we have set forth fully *supra*, under the name of that author. We may, however, mention that, in this second book of the "*Continens*," occurs the famous passage on cataract extraction which has been so often referred to as proving that the modern mode of extracting cataract was invented by Antyllus. The passage in question runs as follows (in the Latin translation, the Arabic original being lost): "Dixit Antilos: Et aliqui aperuerunt sub pupilla et extraxerunt cataractam: et potest esse, cum cataracta est subtilis; et cum est grossa, non poterit extrahi, quia humor egrederetur cum ea. Et aliqui loco instrumenti posuerunt concilium vitreum et sugendo eam suxerunt albugineum cum ea." The fact is, however, that, until the absolute demonstrations of Brisseau and Maitre-Jean in 1705, it was not even known that a cataract is an opaque crystalline lens, the supposition being that the morbid affair consists of an inspissated humor which has "flowed down" (hence the term "cataract") into the space or chamber imagined to exist between the crystalline lens and the pupil. See *supra*, **Antyllus**.

A small book of Ar-Razi's, but even better known, perhaps, than the colossal "*Continens*" is the so-called "*Medical Work* [dedicated] *to*

Mansur," Mansur having been, at the time, the Prince of Khorassan. In the ninth "book" of this little work occur the following "chapters," or sections, which deal (in far too brief a manner) with ophthalmologic subjects: (16) Ocular Ulcers, (17) Foreign Bodies, (18) White Spot [Leucoma], (19) Trachoma and Pannus, (20) Itching of the Corners of the Lids, (21) Pterygium, (23) Epiphora, (24) Weakness of Vision, (25) Hyphæma Conjunctivæ [Subconjunctival Ecchymosis], (26) Trichiasis, (27) Cataract, (28) Nightblindness, (29) Enlargement of the Pupil, (30) Lacrymal Fistula. Highly condensed as the ophthalmic portion of the Mansurian treatise is, it nevertheless contains the most important contribution of Rhazes to ophthalmology—namely, the first, absolutely the first, mention in history of the pupillary contraction resulting from the action of light, in other words the pupillary light-reflex. The passage in question is as brief as it is memorable: "In the middle of the icy humor [iris] appears a hole which now dilates and now contracts, according as the icy humor feels the need of light; it contracts when the light is strong, and dilates in obscurity. The hole is the pupil, and the membrane is called 'the uvea.' "[73]

Then, too, besides the great "*Continens*" and the little treatise dedicated (or rather intituled) to Mansur, Ar-Razi composed a number of medical monographs, some of which are of great ophthalmologic interest. The titles of those of the latter sort are as follows:

1.—*Why the Pupils Contract in the Light, and Dilate in Obscurity.* (Ar-Razi was very much interested in this highly important subject.)

2.—*On the Nature of Vision: Wherein is Shown that the Eyes are not Radiators of Light.* (The great independent thinker combatted the prevalent theory that beams of energy proceed from the eye, mingle then with the surrounding atmosphere, and, proceeding to the objects of sight, surround it, and then return to the eye with information about the object looked at. However, this view had been combatted before the time of Rhazes, and, as we shall see hereafter, was finally and forever vanquished by another immortal Arab, Ibn al-Haitam.)

3.—*On the Conditions of Sight.*

4.—*On the Form of the Eye.*

5.—*The Book of the Surgical Treatment of the Eye.*

6.—*Circular Letter to his Student, Joseph ben Jacob, on Ocular Medicines, Ocular Treatment, and The Combination of Medicines for Certain Purposes.*

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[73] See P. de Koning, "*Trois Traités d'Anatomie Arabes,*" 1903.

An important, but not especially original, Arabian ophthalmologist, was Ali Abbas, the full form of whose name is Ali ibn al-Abbas al-Majus—i. e., the magician, or fire-worshipper. He is also often called Haly Abbas. This distinguished Persio-Arabian was born in the tenth century and died 994. He was body-physician to the Emir, Adhad ed-Dauda. His chief work is "*al-Maliki*," "*Liber Regis*," or "*The Kingly Book*," so called because of its dedication to the Emir above-mentioned. The work is divided into two parts—a theoretical and a practical, of ten books each. The author declares his intention in the composition of the work to have been the production of something which should constitute a kind of golden mean between the extremely prolix and ill-digested "*Continens*" of Rhazes, on the one hand, and the over-condensed and much too highly systematized "*Liber ad Mansorem*" of the same distinguished writer, on the other. The result is decidedly satisfactory, for all historians of ophthalmology agree that "*The Kingly Book*" is a model of completeness combined with concision.

In "*The Kingly Book*" the diseases of the eye are treated, first, in the 13th chapter of the 10th book of the 1st part. The subjects are all discussed, as one might readily suppose, in exact anatomical order. In the second (the practical) division, he speaks for the most part of the cataract operation, as it was practised in his day. Of the cataract operation, however, as practised among the Arabs, we shall speak hereafter in connection with Tabari and especially in connection with the greatest of Arabian ophthalmologists, Ali ben Isa.

Next in time we come to Tabari, whose name, in full, runs Abul Hasan Ahmad b. Muh. at-Tabari. This distinguished oculist, who flourished 970 A. D., was body-physician of the Emir Rukn ad-Daula. He composed an important work entitled "*The Therapeutic Book of the Eye*," which, very unfortunately, has not come down to our day. He also wrote a comprehensive treatise on general medicine, which he called "*Hippocratic Treatments*," in ten books. Of these, the fourth is devoted to the eye, and is still extant. Its contents will be given in a sufficient summary in the sketch of **Tabari** *infra*. Suffice it for the present that Tabari was remarkably free from superstition for his day, and marched in the great company of Hippocrates.

And now we come to one of the most distinguished, and by far the most original, of all the Arabian oculists, Abul Qasim Ammar b. Ali al-Mausili—inventor of the suction operation for cataract. Ammar was born at Mosul, in Mesopotamia, in the latter half of the 10th century. He made a number of pilgrimages, both for the purpose of study and for that of practising ophthalmology, dwelt for a time in

Irak, and, finally, settled for the practise of his profession in Egypt. In this land it was, during the reign of the Sultan Hakim (996-1020 A. D.) that Ammar composed his highly original book, and, possibly, invented his suction method for the extraction of cataract. At all events, the suction method is undoubtedly Ammar's, and his great treatise, entitled "*Book of the Selection of Eye-Diseases*," is the most important work on ophthalmology now extant from the Middle Ages, with the single exception of the "*Memorandum Book for Oculists*" of Ammar's great contemporary, Ali ben Isa.

The most decidedly interesting passage in the book is that relating to the suction-operation for cataract—a passage which is given in full in the sketch of Ammar in this *Encyclopedia*. Long before Ammar's time certain attempts had undoubtedly been made (e. g., by the ancient Greek, Antyllus) to remove soft cataracts by suction. These endeavors, however, had been hesitating, and half-hearted, as well as awkward and probably without success. All had been performed (so far as that word is applicable) by the corneal route, and the escape of aqueous humor had been looked upon, both in antiquity and in the middle ages, as an irreparable disaster. Further, the attempts at suction had, in these early instances, been made by means of a glass tube. Ammar avoided "the aqueous calamity" by entering the eye through the sclera, and then, as above related, had removed the cataract by suction through a hollow needle of his own invention.

Ammar's suction procedure was a more important matter in his land and day than would appear to us on first consideration. Cataracts were frequent there and then, and, in the great majority of instances, were soft. However, the operation did not by any means receive the recognition which it so manifestly merited. Favored sufficiently by the operators of the Orient, it nevertheless did not manage to secure in Western Islam more than a bare recognition. Thus, in Spain, it was really never adopted to any considerable degree. In Christendom the excellent little procedure fared even worse. Merely mentioned by Guy de Chauliac and one or two other authorities of the Christian Middle Ages, it was laid aside for centuries (almost a millenary) until indeed a time within the memory of men now alive—1846. In that year, the procedure was revived by Blanchet.

And now we come to the greatest of all Arabian writers on surgery, Albucases, who is also known as Abulkasim, Abulcasis, Albucasis, Bucasis, Alzaharavius, etc., and whose actual name, in full, was Abul Kasim ben Abbas al-Zarawi. Albucases was, in fact, a Spaniard. The place and date of his birth are not known, but he died extremely old, at Cordova, Spain, A. D. 1013. His surgery formed only a part of his

great general work on medicine, "*al Tasrif*," ("The Explanation"). Based chiefly on the Greeks, especially Paulus of Ægina, it exhibits, nevertheless, considerable evidence of a rich personal experience and the keenest powers of observation. The illustrations of surgical instruments in this work are particularly interesting. Like many another prophet, Abul Kasim was largely without honor, not merely in his own land, but even in his own age. A much belated, if well deserved, recognition was, however, accorded to him ultimately, throughout Western Europe; and, indeed, it was chiefly owing to the fact that the masterful and comprehensive *al Tasrif* was translated into excellent Latin and then widely circulated in mediæval Christendom that the attention of European scientists was eventually directed to the highly valuable writings of Arabian ophthalmologists. Even at the present day, *al Tasrif* constitutes easily the most copious and most valuable fountain of knowledge concerning Arabic surgery, ophthalmic and general, and its distinguished author must be accorded a place in Arabic medicine second perhaps only to those of Rhazes and Avicenna.

The ophthalmic parts of the great book are scattered more or less throughout the surgical division generally. Now, the surgical section falls into three books, the first of these relating to cauteries, the second to incisions and bloody operations in general, the third to the setting of dislocated bones. In the second book occur most excellent descriptions of twenty-three operations on the eye, as these were performed about 1000 A. D. Though all these operations are described very briefly, the language is simple and clear, and, in a word, Albucases as an ophthalmologist is only surpassed, among the Arabs, by Ammar and by Ali ben Isa.

The greatest of all Arabian physicians was Avicenna, who was also known as "The Prince," or "The Chief," and whose name in full was Abu Ali al-Husain b. Abdallah b. al-Husain b. Ali-as-Saih ar-rais Ibn Sina. Born at Khorassan A. D. 980, he knew at the age of ten the Koran by heart, and the greatest difficulty which his teachers met in connection with their instruction of this wonderful pupil was to keep him supplied with subjects. At the age of 17 he was called in consultation in the case of the Emir, Nuch ben Mansur, and acquitted himself most creditably.

The death of his father—a high official at Bokhara—having left him rich, Avicenna began a life of dignified and successful wandering. He passed from court to court in the various capacities of physician, astronomer, author, teacher, and, finally, vizier—a dignity which he reached in Hamadan. For the rest of his life we refer to his sketch in this *Encyclopedia*, adding here that he died 1038 A. D.

Avicenna was a very prolific and interesting writer. His works, declared to amount in number to 105, were in prose and in verse, and treated of law, astronomy, philosophy, mathematics, statesmanship, and medicine. He was not an original medical writer, but was an excellent compiler. His medical *magnum opus*, "*Kanun*," ("Canon") was only a sort of combined codification and amplification of Galen, Paulus, and others of the Greeks. The literary form, however, was so delightful that the book at once took rank above the "Kingly Book" of Ali Abbas and even the "Hawi" of Rhazes. It became the "Canon" indeed not only for its own immediate time and place, but also for Western lands through half a thousand years.

Though chiefly a general practitioner, Avicenna also deserves high praise as an accurate and logical ophthalmologist. His writings on the eye are comprised in the third division of the third book of "*The Canon.*" As an ophthalmologist, however, Avicenna wrote, it would seem, from an inextensive personal experience in the treatment of eye-diseases. He has also been severely criticised for paying too little attention to the most important subjects—for example, trachoma and cataract.

Next after the greatest of Arabian general physicians came the greatest of Arabian writers on the eye, Ali ben Isa, who flourished at Bagdad in the first half of the 11th century. His "*Memorandum Book for Eye-Doctors*" was the earliest special work on ophthalmology from any age which has been preserved entire, and it stood, furthermore, as the standard text-book on its subject not only in Islam, but also throughout Christendom for several centuries. Even today it is in use among the Arabs. It underwent, soon after its first appearance, two Latin and one Hebrew translations. The only complete translation, however, into a modern European tongue is that of Hirschberg and Lippert ("*Ali ben Isa, Errinerungsbuch für Augenärtzte, aus arabischen handschriften übersetzt und erläutert.*" Leipzig, 1904). Inasmuch as I have already given the substance of this book in the course of its author's sketch, I refer the reader thereto.

An Arabian mathematician, named Alhazen, or ibn al-Haitam, is of very great importance to ophthalmologists because of his services in the field of physiologic and geometric optics. His full name was Abu Ali Muhammad b. Al-Hasan ibn Al-Haitam al-Basri. He should be confounded neither with the physician, Abd ar-Rahman b. Ishaq b. al-Haitam, who came later, nor with another Alhazen—he who, in the 10th century, translated Ptolemy's "*Almagest.*" Born at Bâsra, or Bassora, 965 A. D., he became at first a famous mathematician, of especial renown in applied mathematics. His fame in fact went even

to Egypt, where it reached the ears of the Caliph Al Hakim (reigned 996-1021). The Caliph therefore called upon him so to regulate the waters of the Nile that none of the regular overflows should fail to appear—a calamity which, at that time, had recently occurred on a number of occasions. Al-haitam, or Alhazen, having boasted his ability to do this very thing, was obliged to accept the difficult task. As a matter of course, he failed to regulate the flowings of the Nile, and thereby roused the anger of the Egyptian potentate to such a degree that he had to remain in hiding until that monarch's death. Emerging then from his lurking-place, the mosque of Al-Hazar, Alhazen lived at Cairo till he died in 1038.

Alhazen wrote nearly two hundred works, the most of which, however, are merely extracts, commentaries and paraphrases of the ancient Greeks. His subjects well-nigh cover the fields of mathematics, physics, astronomy and medicine. Two of his own original works concern in a high degree the history of ophthalmology, namely: (1) *Perspectiva* (also called *Optica* and *De Aspectibus*) and (2) *De Luce*. The *Perspectiva*, which had been composed in Arabic, was rendered into Latin by an unknown hand some time in the 13th century, and into Italian in 1341 by Guerruccio de Cione Federighi, court astronomer to Alphonso X, King of Castile. The Latin translation was published by F. Risner at Basel in 1572, and a copy of the original Arabic version is contained in the Vatican Library. The more important portions of the work can be found, at least in substance, in a most excellent article by Hans Bauer, entitled "Die Psychologie Alhazens, auf Grund von Alhazens Optik Dargestellt" (*Beiträge zur Geschichte der Philosophie des Mittelalters*, Bd. X, Heft 5, Münster i. Weimar, 1911). To this very thorough article the present writer desires in fact to acknowledge his indebtedness for much of the material employed herein on the subject of Alhazen's *Perspectiva*.

The second of the works of Alhazen possessed of importance for ophthalmologists is known as "*De Luce*." Written in Arabic, it recently received, at the hands of Baarman a German rendering which is said by Arabic experts to be most excellent ("Abhandlung über das Licht von Ibn al-Haitam." *Zeitschrift der deut. morgenländischen Gesellschaft*, Bd. XXXVI, p. 195, Leipzig, 1882; the Arabic text accompanies the translation).

We shall here discuss in some detail the special value of the *Perspectiva*, and then proceed to submit our English rendering of Baarman's German translation of "*De Luce*," in accordance with the plan of presenting in this *Encyclopedia*, and in English, all the briefer classics in ophthalmology. These two books, let it be remembered,

forever superseded the optics of the ancient world. They are therefore unquestionably worthy of considerable space.

In the very first place, however, it is necessary to protest against the over-enthusiasm shown by Bauer for Alhazen as an ocular anatomist. Thus, in summing up in his own words Alhazen's anatomy of the eye, Bauer says: "Der hintere Teil hat eine durchsichtigkeit, die der des Glases nahe kommt, weshalb für ihn schon bei Alhazen die Bezeichnung *humor vitreus* sich findet." But the *humor vitreus* of Alhazen is nothing but the *ὑαλοειδές ὑγρόν* of Galen, who wrote 800 years before the Arab's time. Then, too (p. 71), says Bauer:[74] "Wie wir in obigen Auseinandersetzung gesehen haben, gibt Alhazen als erster eine zusammenhängende anatomische Beschreibung des Auges." But Galen's *Anatomy of the Eye* (as we have seen already in this article) was a "zusammenhängende," and, what is more, would seem to be very much completer than the ocular anatomy of Alhazen.

It is not in the field of anatomy, or even of physiology, that Alhazen deserves to be remembered, but in that of optics. In fact, it is not too much to say that the wonderful Arab was really the "father" of optics, both geometric and physiologic.[75]

His services in chief (to change the figure somewhat) may be listed as follows:

1. He dealt an absolute death-blow to the strange, unfounded theories of ancient philosophers and physiologists concerning the nature of vision and of light which had hitherto prevailed. These views may here be stated as follows: (a) Rays emitted from the eye merely run out, antennæ-like, to the objects of visual perception, and then run back to the eye with information. (Alkmaeon, Empedocles, Euclid, the Stoics, Kleomedes, Plutarch, Galen.) (b) The rays running out from the eye melt and mingle with rays which come from the object, and then return to the eye with information. (Plato.) (c) Minute, but yet material, images are continually being cast off from all illuminated bodies, and, of these (which flow, of course, in all directions) a number are bound to enter the pupil of any given onlooking eye. (Held by the Atomists and Epicureans, and probably also

[74] Thus, in similar vein, Elsässer, in "D. Bedeutung Leonardo da Vincis f. die exakten Wissenschaften," (*Preussische Jahrbücher*, Bd. 97, Juli-Sept., 1899, p. 290: " * * * Alhazen, der zuerst eine eingehende Beschreibung des anatomischen Baues des Auges giebt * * * ."

[75] As elsewhere stated in this article, the ocular anatomy and physiology of Galen prevailed uninterruptedly until the 18th century. So, too, did the ocular pathology, surgery, materia medica and therapeutics of Aëtius—with a very few changes, of course. It was only the subject of optics, of all the branches of our art, which did not wholly endure until the same quite modern period—owing, of course, to the intervention of Alhazen (965-1038), of Roger Bacon (1214-1294) and, we may add, perhaps, of Leonardo da Vinci (1452-1519).

by the Pythagoreans.) [76] From the time of Euclid, who made the first attempt to explain the visual act by geometric diagrams, the view was held, clear down to the time of Alhazen, that the visual rays, proceeding from a point within the eye, expanded, as it passed out toward the object, into what was called "the visual cone," the base of the cone, finally, coming to rest upon the object looked at. Now, so long as this erroneous fundamental conception both of the nature of light as something which passes from eye to object and also of the rays as of something grouped in the shape of a cone whose apex lies within the eye, while its base is set upon the object looked at, it was clearly impossible for any adequate science of optics to be developed. The whole subject was founded on a mistake. The colossal service of Alhazen, then, consisted in teaching the world that visual rays pass not from eye to object, but from object to eye, and that an infinite number of rays are emitted or reflected, as the case may be, from each and every point comprised within the surface of that object. This service alone would justify for this mediæval Arab the title of "Father of Modern Optics." [77]

2. The same Alhazen was the first to show that the angle of incidence is equal to the angle of refraction, and that the perpendicular to the plane of incidence, the incident ray and the emergent ray, lie all in the same plane.

3. He was further the first to solve the so-called "problem of Alhazen"—i. e., the situation of the eye being given and that of an object which is visible in a mirror, find the point of reflection.

4. He solved almost innumerable problems in catoptrics and dioptrics, which, until his day, had been insoluble. As pointed out by Bauer, his handling of these problems "is more extensive by far than that in the present-day text-books of experimental and theoretic physics."

Coming now to the second of the works of Alhazen possessed of ophthalmic interest, we here submit our own complete translation of Baarman's German rendering of the Arabic original of "*De Luce*."

"In the Name of God, the Allmerciful! The Work of Hasan ben al Hosain ben al Haitam On Light.

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[76] The sceptics, of course, in accordance with their governing principle, believed that the human mind is unable to determine with any precision the nature of vision and of light. Hippocrites and the Hippocratists generally seem to have paid but little attention to the subject. Celsus overlooked it absolutely.

[77] Aristotle (B. C. 384-321) of all the ancient philosophers had foreshadowed the coming view that light consists of radiations not from eye to object but from object to eye. The question of "the visual cone," however, had never been broached in his day—this conception being, in fact, the product of Euclid (about 280 B. C.).

"The treatment of the 'what' of light belongs to the natural sciences, but the treatment of the 'how' of the radiation of light requires the mathematical sciences, on account of the lines along which light extends. Likewise, the treatment of the 'what' of the rays belongs to the natural sciences, but the treatment of their form and appearance to the mathematical sciences. And the same is the case with transparent bodies into which light enters: the treatment of the 'what' of their transparency belongs to the natural sciences and the treatment of the 'how' of the extension of light within these bodies, belongs to the mathematical sciences. So, then, the treatment of light, of the ray, and of transparency must of necessity be compounded of the natural and of the mathematical sciences.

"Since, then, we have settled that, we will now proceed to the explanation of these conceptions, and will lay down as a general proposition that every characteristic which is found in any of the natural bodies and which belongs to those characteristics by which the nature of those bodies is constituted, is called an essential property, precisely as the nature of every object consists solely of the sum of all the characteristics present in that body, which, so long as its nature does not become some other, is inseparable from it. Now, the light in every self-luminous body is one of the characterstics by which the nature of that body is constituted, and so the light in every self-luminous body is an essential property of that body, and the accidental light, which is visible on the opaque body upon which it streams from other bodies, is an accidental property. This is the view of those who are familiar with the science of philosophy.

"Now, as to the mathematicians, they believe that the light which radiates from the self-luminous body, and which is an [essential] [78] property of that body, is a fire heat, which exists in the self-luminous body; and indeed because they find that, when the sunlight is reflected from a concave mirror, and so is collected in a single point, and in this point any sort of combustible body is placed, this body, at the moment when the rays are collected, is burnt up, and also because they find that, when again the light of the sun streams upon the air, the air is warmed, and when the light of the sun, streaming upon one of the opaque bodies, remains upon it for any considerable time, this body is perceptibly warmed, so, because of these phenomena, they are firmly convinced that the light of the sun is a fire heat.

"Then they believe that all the light phenomena are of *one* kind, that is to say, that all are a fire-heat, only these are distinguished by 'stronger' or 'weaker.' And when anything is kindled by light, that happens because of its strength, and when anything is not kindled, that is because of its weakness, precisely as is found to be the case with fire-heat. That is, the fire warms whatever part of the air is adjacent to it; and all the air which is near the fire-body is warmed more strongly than that which is distant. And when in the air which is adjacent to the fire, but whose distance from it is still to a certain degree considerable, a combustible body is placed, it does not consume;

[78] All the bracketted matter consists of interpolations by Baarman.

but if this body is placed nearer to the fire, and is set in the air which clings to the fire-body, then this body does consume. Now there is no other difference between the air which clings to the fire-body and the air which is distant from the fire, than this, that the air which clings to the fire has a stronger heat. So there is a fire-heat in each of the two air spaces: the one [air space] is the kindling, and its heat is strong, but the other is not kindling and its heat is weak. Likewise, light is a fire-heat; whatever part of it is strong, will kindle, but what is weak, does not kindle. Consequently, every light is, according to mathematicians, a fire-heat, and it becomes visible on the luminous body in precisely the same way as fire becomes visible on a body bearing fire.

"Those self-luminous bodies which are intelligible to sense perception are of two kinds, namely the stars and fire. The light of these bodies radiates upon everything which is near them, and this fact is comprehended by the sense perception. Now, in our book on optics, in the first chapter, we have explained that every light in every luminous body, whether it be essential therein or only accidental, that that light radiates out upon every object standing opposite, and we there explained this fact in detail. It should indeed be added that induction in this matter completely satisfies, for no opaque body can be found standing over against a luminous body, without its being seen at the same time that the light of this luminous body appears upon every opaque object, if between the two there is nothing hindering or any great distance, and if the light in the luminous body is not extremely weak. In all natural bodies, the transparent as well as the opaque, there is a power to receive the light, in consequence of which they receive the light from luminous bodies. But in transparent bodies, besides the power to receive light, there is also a power which conducts the light on farther, that is, transparencies: and the bodies which are called transparent are those into which light enters and which let the eye perceive that which stands behind them. These bodies are divided into two classes, for light penetrates them in two ways. The one class consists of those throughout whose entirety light penetrates, and the other class of those into certain parts of which light penetrates, into others not. To the class which light completely penetrates belong air, water, glass and whatever is similar to these things. For, in the case of thin fabrics, the light penetrates the pores which lie between the threads, but does not penetrate the threads themselves, for the threads are opaque bodies, into which the light does not penetrate. Because, however, the fine threads of the thin fabric are extremely fine, the particles of light which pass through the pores of the fabric are, for the eye, not to be distinguished from those which are caught by the threads thereof and reflected, but the eye perceives only the light rays on the other side of the thin fabric, which press through the meshes. Moreover, the light rays which are caught by the threads and reflected, are, both because of the fineness of the pores and because of the fineness of the threads, not to be distinguished by the eye from the others, for the eye does not generally perceive everything that is extremely fine. Therefore the transparency of the air, water, glass and similar substances is not the same transparency as exists in thin garments. The

truly transparent, then, is that into whose totality the light enters, as air, water, glass and similar substances; while thin fabrics are only called transparent by reason of their similarity to these substances in respect to the penetration of light.

"Now the transparent bodies have been distinguished from others, we assert that in those transparent bodies which light penetrates completely, there is a power to receive light, exactly as is the case in opaque bodies. This shall be proved for each of the two kinds; by 'the two kinds' meaning the opaque and the transparent bodies, whose entire body is penetrated by the light. A proof of this, that in all opaque bodies there is a power to receive the light, is that the following is true of every opaque body: if it stands opposite to a luminous body, with nothing of a hindering nature between the two, while the light in the luminous body is not extremely weak, and the luminous body remains opposite the opaque body for a perceptible length of time, then the person who is looking upon the opaque body perceives the light on the surface of the opaque body a perceptible length of time, if the opaque body is not extremely distant from the eye and also not extremely distant from the body in which the light is. The fact, now, that the eye perceives the light on the surface of the opaque body for a perceptible length of time is a distinct proof of this, that on the surface of the opaque body is a light which remains constantly upon its surface as absolutely no phenomenon appears continually on any given body except when in this body a power exists of accepting this phenomenon; for, that the body accepts a phenomenon signifies nothing else than that this phenomenon is constant in this body. Hence, the becoming visible of the light on the surfaces of the opaque body is an evident proof of this, that in opaque bodies a power exists to receive the light.

"As to transparent bodies, their nature is still easier to set forth. That is, in transparent bodies the light penetrates, and the light which has penetrated them becomes visible on such opaque bodies as stand behind them, if the transparent body is in the middle between the luminous and the opaque body. The light remains on the opaque body which stands behind the transparent body, so long as the luminous body remains opposite the opaque one. If, now, the light, which is visible on the opaque body, only radiates from the luminous body into the transparent body and then presses onward to the opaque one, then the light, so long as it remains on the opaque body, remains also in the transparent one. A proof of this, namely, that the light remains in the transparent body after it has penetrated into it, is this: if the transparent body is intersected by an opaque body, at whatsoever spot the intersection occurs, then the light on this opaque body intersecting the transparent body becomes visible. This fact appears plainly, when the transparent body is air or water. And so the becoming visible of the light on the opaque body which cuts the transparent body at any given place, is a manifest proof of the fact that the light remains in the transparent body. If, however, the light remains in the transparent body, then there must be in the transparent body a power to receive the light, as has been explained already. So it ap-

pears, from what we have presented, that in each of the bodies, the finely transparent as well as the opaque, a power exists to receive the light.

"That, in a transparent body a power exists to conduct the light on farther (a power which is not in opaque bodies) that is evident: for into every transparent body light penetrates, and into every opaque body light does not pentrate. And so, from that, it is clear that in a transparent body there is a property which does not exist in those which are opaque; and because light penetrates into every transparent body and not into any kind of opaque body, in which there is no transparency at all, then that which conducts light on farther is the transparency; and inasmuch as transparency belongs to the characteristics through which the 'what' of the transparent body is constituted, then the transparency is an essential characteristic in the transparent body.

"It is, then, clear from all that we have said, that in every natural body there is a power to receive light, and that, in the transparent ones among them, at the same time with the power to receive the light, another property is present which conducts the light on farther, and it is at the same time clear that transparency is an essential characteristic, whereby the 'what' of the transparent body is constituted. Now transparent bodies are various: their transparency is various and various also is their reception of the light and their sending of it farther on. We shall describe all this, after we have completely described light. As, now, we have already shown that the light of a luminous body radiates upon every object which stands over against it and which is somewhere near it, it still remains to explain *how* the light radiates upon the objects which stand over against it, and *how* it penetrates into the transparent neighboring objects. In this connection we assert first of all that light radiates from every luminous body, and penetrates into every transparent body which is near that luminous body, and becomes visible on every opaque body standing over against that one which is luminous. That fact is clear; it requires no proof, and indeed because the light of the sun, of the moon and of the stars penetrates into the body of the sky, which is a transparent body, and into the body of the air, which also is transparent, becomes visible on the upper surface of the earth and upon earthly bodies, penetrates into water, and, if the water is in a transparent vessel, becomes visible on every opaque body which stands behind this vessel. And likewise, when light radiates on transparent minerals, as glass, crystal, and things resembling these two substances, and behind them there is an opaque body, the light becomes visible on the opaque body. From the consideration of these instances, it appears very clearly that light penetrates into opaque bodies.

As to the way and method whereby light penetrates into transparent bodies, that occurs in this way: the light passes forward in transparent bodies on rectilinear paths, and indeed it passes along such paths only; and it proceeds from every point of the luminous body in the direction of every straight line which can be drawn from such point into the

transparent and adjacent body.[79] This, too, we have already explained in detail in our book on optics; but yet we will now mention from all that something which will be sufficient for our present purposes. In this sense we say that the passing forward of the light along straight paths is made entirely clear by the light which enters through a chink, or fissure, into a dark room.[80] For, when the light of the sun, or of the moon, or of fire, enters a room through a chink of moderate size, and dust is in the room or else is stirred up in it, then light which enters through the chink becomes visible in the dust which is mixed with the air; and it becomes visible on the floor or on the wall of the room which stands opposite to the chink. And the light from the chink is found extending to the floor or to the wall which is opposite to the chink, along straight lines. And, if a person holds a straight staff along this visible light for purposes of comparison, then he finds that the light runs along the straight line of the staff. If, however, no dust is in the room and the light appears on the floor or upon the

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[79] This observation, so far as I have been able to ascertain, is absolutely original with Alhazen, and it alone would suffice to render him the father of optics, both geometric and physiologic, for the principle, or fact, in question is the basis, the absolute foundation, of all optical science. Far less important indeed was the discovery, or, rather, the invention, many centuries later, of the undulatory theory of light.

The principle in question was re-discovered by Christian Huygens (1629-1695), and is therefore often called "the principle of Huygens." It should, however, be known as "the principle of Alhazen."

It should also be recalled once more, that, in the constructions of Euclid, the rays proceeded from the eye to the object looked at, that even these rays were not of infinite number, but only extended along *certain* of the possible lines which might be drawn, and that, moreover, instead of a cone from each and every point of a luminous or illuminated object the base of which cone was the periphery of the pupil of the eye, there was *just one* cone—i. e., whose apex lay at the center of the eye, and whose base was applied to the object looked at. Plainly, but little advance in optics was possible, so long as such a view prevailed.

[80] It is hardly necessary, perhaps, to call the reader's attention to the fact that here is the very beginning of the "camera obscura"—a contrivance of great importance to ophthalmologists, because the principle involved was later to be invoked as that whereby the optical action of the eye was to be explained. But see Wiedemann (*Sitzungsberichte der physikalisch-medicinischen Societät in Erlangen*, Bd. 39, S. 247, 9), who assigns the absolute priority to al-Kindi, another Arab, *ca.* 750-850. Alhazen, however, went very much beyond al-Kindi, at least in his writing, "On the Shapes of the Darkness in Eclipses of the Sun," in which he not only describes the observations made by him of the shapes in question by means of the camera obscura, but in which he mentions also (and was first in history so to do) the dark-room inversion of the image. Next, al-Farisi, an Arab who died about 1320, gave a thorough elucidation of the theory of the camera obscura in a commentary by him upon Alhazen's "*Optics.*" Vitellio (13th century) and Peckham (1222-1291) discussed the camera. Bacon, then, in his *Opus Majus* has the following interesting passage: "We let the sun's rays fall through a small triangular opening in the wall of a dark room. If we catch the image at different distances, we find that this, at a certain distance from the opening is similar to the shape of the aperture, while, at a greater distance, it gradually takes a form which corresponds to that of the luminous body, so that, if this body be spherical, the projection is a circle, and, if it be sickle-shaped, like the sun during an eclipse, then it is given a curving form." Lastly, Leonardo da Vinci (of whom much more hereafter) developed the camera considerably, and added a number of excellent drawings. He is as a rule regarded as the inventor of the camera obscura and also the first to observe that the eye as an optical instrument is really a contrivance based on the same principle as the camera.

wall which is opposite to the chink, and then a staff is erected between the visible light and the chink, or between the two a thread is tightly stretched, and then between the light and the chink an opaque body is placed, then the light becomes visible on this opaque body and disappears from the place on which it had been visible. If, then, the opaque body is moved to and fro in the stretch of space which runs in a straight direction alongside the staff, the light is found to be always visible on the opaque body. It is, then, from all this, clear that the light from the chink to the place at which it is visible, runs forward in straight paths. Now, we have already shown in the book on optics, how the progress of light in every sort of transparent body is investigated: the compass within which we have described it here is sufficient.

"The advance of light in transparent bodies is a physical property of all kinds of light. Sometimes it is indeed said that the expansion of light in transparent bodies along straight paths is a property of transparent bodies. But this view is too false to require proof or attention, and the first acceptation is the correct one. If, that is to say, the advance of light in transparent bodies were a property of the transparent body, then the advance of the light would occur only along special paths, but so the matter is not found, for the light in transparent bodies is found progressing on paths of lines, which intersect one another or are parallel, or intersect one another and do not intersect one another at the same time, and proceeding from the light of *one* body; and indeed that happens for this reason, because from every point of the luminous body, light advances along every straight line which permits of being drawn outward from that point. And therefore the light rays which proceed from two different points lying in the luminous body, must intersect one another:[81] I mean that the lines proceeding in every direction from one of the two points mutually intersect with those lines which pass out upon all sides from the second point. If, now, at *one* time a number of luminous bodies are present, and light passes out from each and all of them, then the location of the lines, along which all these light rays are progressing, is very diverse indeed. Therefore it sometimes happens that the advance of the light proceeds in contrary directions, when the luminous bodies, with reference to the transparent body, lie on opposite sides. Accordingly, the view that there are special paths for light is worthless, and there are no special paths in transparent bodies, which conduct the light further. Moreover, physical motions do not occur from opposed sides. If, now, the light-conducting property, which exists in the transparent body, conducted the light further upon its own straight paths, then that property certainly could not conduct the light further on paths (which, in accordance with their nature, are simple) from two opposed sides. If, now, however, the light in *one* transparent body advances from sides which are opposite to each other, then the advance of light in transparent bodies along straight paths does not proceed from a special property in the transparent body. If, however, light advances only in trans-

[81] The first time in history when this very important fact was given utterance.

parent bodies, and in them only along straight lines, and the advance along straight lines is not a special property of the transparent body, then the advance of light along straight lines occurs only by reason of a special property of light. So it is the special property of light, which moves it along straight paths, and the special property of transparency that it does not hinder the penetration of light into transparent bodies.

"The light, however, passing in transparent bodies along straight paths, is what one calls *ray;* the *ray* is the light advancing from the luminous body in the transparent body along rectilinear paths. The straight lines, however, along which the light passes, are imaginary, not sensibly perceptible, lines. The imaginary lines, now, at the same time with the light which is passing along them, these two together are what is called *ray.* So the ray is a mode of being which extends in a straight line. But mathematicians call the ray of the eyes a ray only by virtue of a comparison with the ray of the sun and the ray of fire. The earlier mathematicians, that is to say, believed that vision occurs by virtue of a ray which is emitted by the eye and which gets back to the eye, and that through such a ray it is that vision occurs, and that such a ray is a luminous property belonging to the genus light; that this is the visual power, and that it passes from the eye along straight paths whose beginning is the middle of the eye; and that when this luminous power gets back into the eye, it perceives the object looked upon. The visual power, extended retilinearly, which proceeds from the center of the eye, together with the straight lines, the mathematicians call *ocular ray.* Those, however, who believe that vision occurs by means of an image reflected from the object to the eye,[82] they are of the opinion that the rays which proceed from the object along straight lines and which intersect in the center of the eye, are light which is still passing onward. Those, that is to say, who are of this view, believe that light extends from every point of a light in the direction of every straight line which may be drawn from this point.[83] When, now, the eye finds itself opposite to any kind of visible object, and, in this object which is looked at, any kind of light is present, whether it be essential or accidental, then there advances light from every point of this light in the direction of every straight line which permits of being drawn between this point and the surface of the visible object. Now there proceeds light (they say) from the eye to the visible object along an infinity of straight lines and in an infinite number of different directions. The imaginary straight lines, however, which permit of being drawn between the center of the eye and the visible object belong to those lines along which light advances, and so the eye perceives the image of the object in the light which is reflected to it solely along the paths of these lines. For whoever is of

[82] The opinion here referred to is that one of the ancient three which held that *actual images* (not rays capable of being focussed into images) were continually being thrown off by all luminous and illuminated objects.

[83] Alhazen speaks here as if the view in question were *already* held by others than himself. But whether those others had or had not originally received the view from Alhazen does not appear. At all events, the earliest record of the view occurs in Alhazen's writings, and I am strongly inclined to the opinion that the view itself was his.

this view believes that the eye by nature is so constructed that it perceives only the light phenomena which are reflected to it along the paths of these lines, and cannot perceive anything which is reflected to it on other than these lines. One calls the light which proceeds along the paths of the straight lines which intersect in the center of the eye, together with these lines themselves, a ray. The ray of the eye is, then, according to all mathematicians, some kind of light which advances along rectilinear paths intersecting in the middle of the eye, and these lines, in and of themselves (and they are imaginary lines) mathematicians call ray-lines. According to the earlier common explanation, however, the ray is a light which advances along rectilinear paths, whether the light is the light of the sun, or the light of the moon, or the light of the stars, or the light of fire, or the light of the eye. This is the definition of a ray; physicists, however, have no scientifically founded hypothesis concerning the ray.

"Now that this is clear, we are going to return to the consideration of transparent bodies. We assert that transparency is a property in the transparent body, and indeed one which leads the light on farther. Transparent bodies are divided into two classes, the heavenly and those which are under the heaven. The heavenly among them are of *one* kind, for the heavenly bodies are of *one* substance. The transparent bodies which are beneath the sky are divided into three kinds: the first of these is the air; the second, water and transparent liquids, like the white of an egg and the transparent layers in the eye, and whatever is similar to these; and the third, the transparent minerals, such as glass, crystal and the transparent precious stones. All these are kinds of transparent bodies. Those transparent bodies are different with respect to their transparency, and in each of these kinds is a varying transparency, except in the heavenly bodies. Thus, the air has a varying transparency; it is in part dense, in part rare. Fog, for example, is dense, also smoke, and air which is mixed with smoke or dust; yet again it is rare, as the layers of air between walls, the air which is near the sky and the air which is mixed with nothing else; the thinner air, however, has the more decided transparency. Likewise, among transparent liquids, one has a greater transparency than another, for example, flowing water in comparison with water with which a little dyestuff has been mixed. [And likewise the minerals:] thus the crystal is more transparent than the hyacinth. All this is attested by the sense perception. As regards the sky body, however, there is no variability to be noted in its transparency, that it is, however, transparent, is obvious; for the stars have varying distances from the earth, but, in spite of that, the eye perceives them all, without respect to their different heights in the skyey spaces.

"In all transparent bodies, however, beneath the sky, there is something of opaqueness; for there proceeds from each one of them, when the sunlight streams upon it, a second light, such as proceeds from opaque bodies when the sunlight streams on them; only that the second light which proceeds from the transparent bodies, is weaker. This subject we have explained in detail in the first chapter of our book on optics and taught the way and manner whereby it is proved for every

light which proceeds from opaque bodies and is found in transparent bodies; in this place we will adduce only somewhat from our former exposition. That from the air a second light proceeds, is obvious from the case of morning light. The surface of the earth is illuminated in the morning before the sun arises, and the sense perception beholds the surface of the earth brighter then than it was in the night, although, in the morning, the sun, before it becomes visible to the eye, does not stand opposite the earth. But light proceeds from luminous bodies only in rectilinear paths; this subject we have explained by reasonings and observational proofs in the book on optics. Now, neither are there between the sun and the earth's surface, on which the sun has not yet shone, any straight ray-lines, nor are these crossed by the terrestrial body. Consequently, that light which is visible on the earth's surface, is not a light which streams from the body of the sun itself. No other luminous body, however, stands opposite the earth, which would be capable of emitting light upon the surface of the earth, than the air which lies between the sky and the earth and which has been rendered luminous by the sunlight. This air, now, stands opposite the solar body, and between it and the sun is nothing which can hinder: this air grows luminous in the morning, and the light which is in it is perceived by the senses. Consequently, the light which is visible on the surface of the earth in the morning, is a light which proceeds from that light which is in the air that is opposite the surface of the earth. Now, of water [in the text 'fire'] [84] to glass and transparent minerals, it is true that, when the light of the sun beams on them, there goes forth from them also a second light, while, at the same time, the light passes through their interior. This light becomes visible to sense perception, when some white body is placed near the water or transparent minerals on some side other than that from which the light which penetrates it is directed. For one observes then on this white body a new light, which, before, was not to be seen there, but this light is weak. The manner and method of the observational proof of this subject we have thoroughly presented in the book on optics; in this place thus much will have to suffice. From each of the transparent bodies, therefore, which are beneath the sky, proceeds, when the light of the sun falls on it, a second light, precisely as it proceeds from opaque bodies, when the light of the sun falls on them; only that the second light which proceeds from transparent bodies is found to be weaker than the second light which proceeds from opaque bodies. Now, we have already shown that, in opaque bodies there is a power to receive light, and, likewise, that, in transparent bodies there is a power to receive light, and have shown that, in transparent bodies, there is a light which remains in them while at the same time the light from without passes through them. We assert now that the radiation of the second light from the transparent body is not a radiation of the light which has penetrated therein. For the light which has passed through the transparent body is directed only toward those sides which are opposite to the body from which the light proceeds, and

[84] Once again: The bracketted matter, throughout this translation, belongs to Baarmann.

toward no others; while the second light which proceeds from these bodies is found to be directed toward the sides which are opposite to these. Hence, the radiation of the second light from the transparent body is not a radiation from the light which has penetrated it. Now there is in the transparent body no light except that which has penetrated it and that which remains within it. The remaining of light, however, in natural bodies, has no other cause than opacity, which is the opposite of transparency; for if in a body there is no opacity then it is transparent. If, now, it is transparent, the light penetrates it; and if the body is transparent in the highest degree and there is in it no opacity of any sort, then the light merely penetrates it, but does not remain in it; for the transparency is the cause of the penetration, not of the remaining. If, however, in every opaque body, the light remains and in every transparent body the light penetrates, then the remaining of the light has no other cause than the opacity. If, now, further, as already shown, in every transparent body which is beneath the sky, there is remaining light, while at the same time the light [from without] shines upon it, then there is in every transparent body which is under the sky, also a certain non-transparency at the same time with the transparency which is in that body. It has also been already shown, that the transparency in these transparent bodies is various. If, now, the transparency in these transparent bodies is different, and, as already shown, in each of these transparent bodies there is some sort of non-transparency, then the various transparency which is in these transparent bodies is only a consequence [of the degree] of the non-transparency which is in them. The greater the opacity which is within them, the less is their transparency; the less opacity there is in them, the stronger is their transparency.

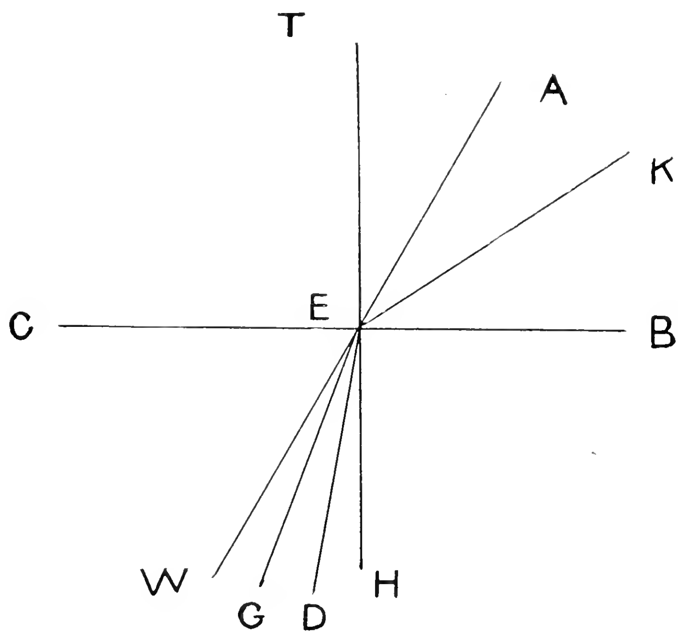
"However, as concerns the transparency of the sky, the Logician [Aristotle] believes that its transparency is purer than the transparency of all other transparent bodies; it is transparent in the highest degree, and it is absolutely impossible that a body should have a greater transparency than that of the sky. Mathematicians, however, believe that transparency has no bounds, and that, with respect to every transparent body, it is possible that there may be some body which is more transparent still. Even one of the later mathematicians makes this matter clear, namely Abu Sa'd al 'Alā ibn Suhail; who has in fact written a treatise in which he expounds the same matter by a geometrical proof. We, also, will adduce the proof of this matter, but will better emphasize its chief points than 'Alā ibn Suhail and give to it a clearer development than his. We assert, then, that every light which beams upon a transparent body enters into this transparent body along straight paths; experience shows this. When, then, the light propagates itself in the transparent body and arrives at another transparent body whose transparency is different from that of the first body, in which it was propagated and falls obliquely on the surface of the second body, then the light is broken (refracted) and does not enter on straight lines. This subject we have explained in the seventh chapter of our book on optics and taught the way and manner of verifying it on every single one of the transparent bodies by means

of observation: we have also proved in the same place that the refraction occurs at special angles. When, now, the refraction occurs from the rarer medium to the denser, then it occurs on the side of the perpendicular which is erected at right angles to the surface of the thicker medium in the point at which the refraction occurs; when, however, the refraction occurs from the thicker medium to the thinner, then it occurs toward the side which is opposite to the perpendicular. When, now, the light is propagated through the thinner medium and is broken in the thicker medium then there arises some kind of angle at the point of refraction; when, however, it propagates itself first through the thicker medium and then is refracted in the thinner medium, then the light which propagates itself through the thicker medium in a broken line, is refracted in the thinner medium at precisely the same angle which arises between the first ray and the broken ray.[85] When, further, the light from a transparent rare medium, is refracted at two media which are denser than the first medium, and the two dense media are of different densities, then the refraction of the light in that medium which has the greater density is the greater; I mean that, when the light is refracted in that medium whose density is the greater, it lies nearer to the perpendicular erected at the point of refraction; when, however, the light from a transparent dense medium is refracted at two rare media and the two rare media are of different rarities, then the light in the medium which has the greater rarity is refracted farther away from the perpendicular erected at the point of refraction. This fact Ptolemy has already demonstrated likewise in the fifth chapter of his book on optics with respect to the ray of the eye; [86] I mean that he has shown that, when the ray of the eye propagates itself in a transparent medium, then strikes another medium whose transparency is different from that of the first medium, falling obliquely on the surface of the second medium, then it is refracted and does not penetrate along a straight line. He has further shown that the refraction of the eye-ray from air to glass is greater than the refraction of the eye-ray from air to water—glass is, in a word, denser than water—and he has there also shown that when the eye lies in the rarer medium and its ray is refracted at the denser medium under any kind of angle, then, however, the eye is placed in the denser medium in the direction of the broken ray, the ray is refracted at the same angle. From all this it is clear that every ray which propagates itself through a transparent medium and then strikes another transparent medium, is, if the transparency of the second medium be denser than the transparency of the first medium, through which it has propagated itself, refracted in the second medium, and that the refraction in the second medium stands in a proportion to

[85] One of the most important discoveries ever made in optics, of course, yet the "index of refraction" was to lie in the "womb of time" till delivered by Snellius (1591-1626).

[86] But, inasmuch as there is no such thing as "the ray of the eye," and as Alhazen was the first to demonstrate the matters in question with respect to rays which actually exist, the meed of priority should, very obviously, be assigned to the Arab.

the density of the second medium[87] (in a denser medium the refractional angle is the larger); and that every ray which propagates itself in a transparent medium and then strikes another transparent medium, is, when the transparency of the second medium is rarer than the transparency of the first medium, refracted in the second medium and that the refraction in the second medium stands in proportion to the rarity of the second medium.[88] Let us give an example of this, in order that the matter may become clear. Let two transparent media which differ in transparency, be given, and let the point A lie in the thinner medium



and, through the point A let a plane surface be laid, which stands at a right angle to the surface of the denser medium, and the section which is common to the two surfaces, I mean the [construed] plane surface and of the surface of the denser medium be the line BC, and let it be straight. Now let us draw from the point A, the ray AE, which falls obliquely on BC and is refracted in the direction of EG. and let us erect at the point E a perpendicular to the surface of the thicker medium, which may be EH, and prolong AE rectilinearly to W. By this we get the angle E. which is obviously the angle of deviation. If, however, a ray is now drawn along the line GE, then it is refracted to the line EA. If one drops the perpendicular HE, then, if at the place of the rarer medium in which A lies, a still rarer

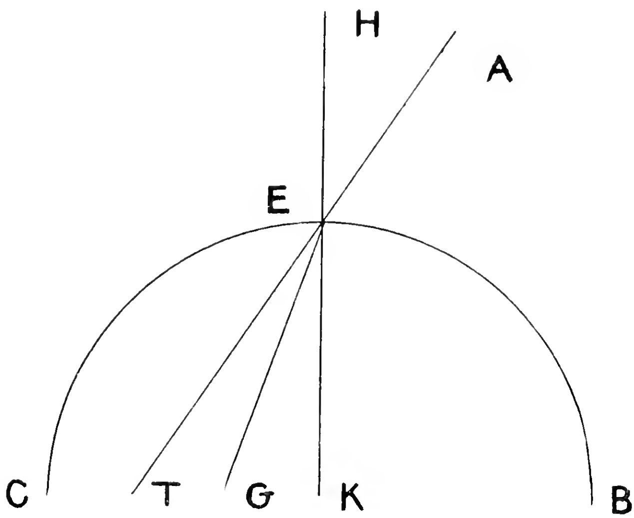
[87] One of the most important discoveries ever made in optics, of course.
[88] Again, one of the most important discoveries ever made in optics.

medium is placed, the ray GE is refracted in a direction which stands farther away from the perpendicular ET. Then the refraction in the medium which is the more transparent may occur in the direction EK. The ray, however, which propagates itself through the denser medium and is refracted in the direction EA, which is nearer to the perpendicular TH, let this ray be the ray DE, which is refracted in the direction EA If, now, a ray propagates itself in the direction AE, and the rarer medium is the [supposed] second medium, which is more strongly transparent, then it is refracted in the direction of ED. If, however, the rarer medium, in which the point A lies, is still more transparent than the rarer second medium, then the ray which propagates itself through the denser médium and is refracted in the direction EA, is, if the transparent rarer medium is the third medium, refracted in the direction of a line which lies still nearer to its perpendicular than the line ED. It is likewise in the case of water: the finer and the more transparent the finer medium is, the nearer the line lies to the perpendicular EH, in whose direction the ray is refracted, and the nearer the refracted ray comes to the line EH, the smaller becomes the angle HED, and it stands to the angle, which arises between the broken ray and the perpendicular, in the proportion to the transparency of the rarer medium. From this it follows necessarily that the 'how' of the transparency stands throughout in proportion to the angle at the refractional point.

"Now, there is no difference of opinion either among mathematicians or among the scientific investigators of nature as to whether every angle is infinitely divisible. For, if one takes the apex of an angle as the center, and at any given distance constructs curvingly an arc which comprises the angle, then this arc permits of division into small parts whose further subdivision has no limit, for the arc which comprises the angle can be divided unendingly. If, then, from its division-points lines be drawn to the apex of the angle, then the angle is divided into any given small parts. Thus, with reference to any angle, there can be yet another angle which is still smaller. If, now, the transparency of the body stands entirely in proportion to the angle of refraction, and there is no angle for which a smaller angle than that cannot be found, then there is also no transparency for which one cannot imagine a rarer than it is. But everything for which one can imagine something still rarer than that is, is not the limit of transparency. Then, therefore, there exists for transparency no limit at which it must remain.

"Ptolemy has already shown that the ray of the eye is refracted at the convex side of the sky-sphere, and that the sky is more transparent than air, and that from this it necessarily follows that the light of the sun and the light of the stars is refracted at the convex side of the sky-sphere.—Now let this problem be propounded. Let the denser medium be assumed to be spherical, and the mutual line between the plane laid through the point A and the spherical surface be the arc BEC, and let its center be K, and let the denser medium be that which is near the center, and the rarer medium that which lies without the convex side of the arc. The point A lies in the rarer medium, and let

a ray AE be drawn to it, falling obliquely on the spherical surface, and let the ray AE be broken in the direction of EG, and we unite KE and prolong it [this uniting line] to H, then EH is a perpendicular in the spherical body. If, then, a ray is drawn to the line GE, then it is refracted in the direction of EA. If, however, the medium which surrounds A is more strongly transparent, then the ray which extends to the line AE is refracted to a line which lies nearer the perpendicular KH. The proof of this is the same as in the case of the straight line. The angle, however, which lies between the broken ray and the perpendicular KH, becomes smaller than the angle GEK. The angle GEK, now, can be divided and diminished to infinity, and one can imagine that the transparency of the rarer medium, in which A lies, increases in transparency and rarity to infinity. If now the rarer



medium is the sky and the sun is at the point A, and its rays are extended to the line AE and refracted to the line EG, then, if the transparency of the sky were purer and thinner than it is, the ray AE would be refracted to a line which lies between the two lines GE [and] EK. Now, an infinite number of lines can fall between the two lines GE and EK, and one may consequently imagine that the transparency of the sky might possibly be purer and rarer than it really is, to infinity.

"That, now, which we have just reported, is the view of mathematicians: I mean that the transparency of the transparent bodies may in thinness and purity increase to infinity—i. e., that one can imagine with respect to every transparency in a transparent body a purer transparency than that. Investigators of nature, however, assert that every property in natural bodies proceeds only to a finite limit, and not to a degree which is infinite; and that angles which permit of division to infinity, are only imaginary angles enclosed by imaginary

lines, that, moreover, the angles which present in natural bodies, are partly real partly only imagined, and could not be divided to infinity, while at the same time the body in which they existed, retained its form of being; for the body in which the imaginary angles occur, cannot be divided to infinity. For every natural body (they say) permits indeed of division to a certain extreme degree, while it at the same time retains its form of being; if, however, it be still further divided, then it loses its earlier form of being and takes on some other. An example of this is supplied by water. When this is divided to the very extreme, it reaches a degree of division which exhibits the smallest possible division of water; if then it be still further divided, then it loses the existence-form of water, and assumes that of air. The air then likewise permits of division into its smallest possible parts; but if it then be divided still further, it loses the existence-form of the air and takes on that of fire. The fire, then, likewise permits of division into its smallest possible parts, farther than which, however, a division is not possible; for there is in reality no finer form of existence than that of fire. If, however, the form of existence of the sky is still finer than that of fire, and it is possible that fire is homogeneous with the sky, then the smallest possible particles of fire are subject to further division and a transition into the substance of the sky. The body of the sky, then, is not divisible; if, however, one should imagine it to be divisible, then its divisibility would likewise extend to its smallest possible parts, but farther it could not be divided; for there is in reality no finer existence-form than that of the sky. If, however, after the division of its finest possible particles, one should imagine it to be still further divisible—if this were possible at all—still one could imagine with the help of all his powers of imagination only a divisibility of dimensions, not of the substance of the sky-body, since, when one imagines the substance of the sky-body to be divisible, this is a division only in the imagination, not in reality.—That the sky is transparent in the highest degree is asserted by the Father of Logic [Aristotle] only in *this* sense, that there exists among natural bodies none which is more transparent than the sky and that, in consequence, we cannot conceive that there is any such body in reality; for he assumes that all kinds of things, whose existence is conceivable, have actually come into existence.

"Both dogmas are correct, I mean that transparency is, in the imagination, unlimited, but, in natural bodies limited, and that the transparency of the sky forms its uttermost limit. That, however, which we have said about transparency and transparent bodies is all that it is necessary to know of our conditions.

"Now, we have completed the presentation of all the conceptions, the explanation of which we undertook in this treatise, and now we will sum up that which, in this treatise, we have presented, in order that it may be a lightening of the burden for him who would grasp these things without investigation into their grounds and proofs. And so we say that that which we have presented in this treatise is as follows: Light is, according to philosophers, in every self-luminous body an essential property founded in its substance, while accidental

light is an accidental property which is visible on opaque bodies upon which light streams. According to mathematicians, light, especially essential light, is a fire-heat; while accidental light is an accidental phenomenon which becomes visible on opaque bodies on which light streams. Accidental light is precisely as visible in luminous bodies as fire is visible in bodies which have been seized by it.[89] A ray, however, is that light which propagates itself rectilinearly through a transparent body, whether it be the light of the sun, or whether it be the light of the moon, or whether it be the light of the stars, or whether it be the light of fire, or whether it be the light of the eye.[90] Transparent bodies are all those into which light penetrates and which permit the eye to perceive what stands behind them. They are divided into two classes: one of these comprising everything through which light passes completely, and the other class those things through parts of which light passes, through other parts not. Those, now, through which light passes completely, are divided into two kinds, namely the body of the sky and the bodies beneath the sky; the latter, moreover, into three classes, namely, air, water, and such fluids as resemble these, and transparent minerals such as glass and transparent gems. The transparency of transparent bodies is a property which conducts the light on farther. Transparency is various: the differences in transparency being observed in angles of refraction. When through two transparent media, whose transparency is different, two rays propagate themselves and the two rays enclose, with the perpendiculars erected at the places of refraction, two equal angles, where the two media are in contact, then are refracted in *one* medium which is denser than those both are, then their refraction occurs in the denser medium in two diversely lying directions, and they enclose with their perpendiculars two different angles at the place where the denser medium adjoins; and that one through which the smaller angle arises, has the greater transparency.

"These are all the points which we have explained in this treatise, and it is now full time to bring the work to a close.

"God, however, we pray for help. The book on light is ended."

A distinguished Persian ophthalmologist of the 11th century was Zarrin-Dast, or Goldhand. Born at Gurgan on the Oxus, he was educated both in his native Persian and in Arabic. His work, "*The Light of the Eyes*," constituted the standard ophthalmologic text-book in Persia for many centuries. The title of the volume was selected, according to the author himself, because he who reads and understands the work, will preserve the light of his own eyes and never require

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[89] I. e., the fire.

[90] Alhazen is still, very obviously, under the impression that some light does, perhaps, originate in eyes—an error which naturally arose in earliest antiquity from the observation that the eyes of many animals are really luminous in the dark, and from the *failure* to observe that, when the darkness is made absolute, the ocular luminosity entirely disappears. Alhazen nowhere seems to have held to the ancient idea that the light rays, which were supposed to have originated in eyes, were the means whereby (antennae-like) the act of vision was accomplished.

the services of the ignorant physician. The book is written in a prolix style, and indeed in question-and-answer form, after the fashion of the work of Hunain (q. v.).

"*The Light of the Eyes*" consists of ten chapters, the substance of which is given with sufficient fullness in the sketch of **Abu Ruh** (or Gold Hand) in Vol. I of this *Encyclopedia*. I may add that the book, because of its richness and fullness and its highly practical character, is, despite its prolixity and the question-and-answer form, plainly indispensable to a complete understanding of the ophthalmology of the Arabian middle ages. Indeed only two ophthalmographers of the time are worthy to be ranked with Zarrin-Dast—Ali ben Isa and Ammar.

A Spanish-Arabian physician, of some importance to ophthalmology in his day, was the so-called Abenguefit. Born of a distinguished Arabian family which had settled in Spain, at Toledo, A. D. 998, he was noted in politics as well as in medicine, and became vizier to the Prince of Toledo as well as physician to the chief hospital in that city. The best of his works were those on general medicine: "*De Medicamentis Simplicibus*" and "*De Balneis Sermo.*" He wrote also, however, a book on ophthalmology, entitled "*Book of the Exact Consideration of the Diseases of the Sense of Sight.*" This was not without influence in Spain for several centuries, but is not now extant in any language. Abenguefit died A. D. 1070 or 1074.

The most distinguished representative of Arabian medicine, however, as well as the most illustrious member of a highly distinguished Jewish family, was Avenzoar, who was also called Abimeron and Abumeron. He was born at Pentaflor, near Seville, in the latter part of the 11th century, and died A. D. 1162. His father and his grandfather were famous philosophers and physicians. Avenzoar himself, however, restricted his studies, or, at all events, his professional work, almost exclusively to medicine. His master in the healing art was plainly Galen, but him the great Arabian, unlike most of the other physicians of the middle ages, did not follow slavishly. He was a true disciple of Hippocrates.

His most important book is "*al-Teisir*" (Alleviation by means of remedies). In this book Avenzoar takes an unusually hopeful view of many diseases, and even (in decided opposition to Galen) declares that amaurosis is curable. Concerning the cataract operation, however, he is decidedly pessimistic, naïvely observing: "Extraction is impossible, reclination permissible only." The ophthalmic portions of his work are not, on the whole, of very great value.

A distinguished contemporary, friend and pupil of Avenzoar was Averroës, who is often called "The Mohammedan Spinoza," and who

was born at Cordova, Spain, A. D. 1126. At first he became a cadi. In 1196, however, he was appointed governor of Andalusia. Being accused by his enemies of heresy, he was soon condemned to exclusion from the community of true believers. He was banished at first to an-Nisada, later to Morocco, where he died. He wrote on a vast variety of subjects—philosophy, philology, astronomy, law and medicine. His chief medical work is generally called by its mediæval Latin title, "*Colliget*" (Kitab al Kullijat, *anglicé* The General Principles of Medicine).

As an ophthalmologist Averroës is greatly inferior to a number of other Arabians—notably Ammar and Ali ben Isa. He is nevertheless important for the history of optics, inasmuch as he wholly departed from the purely theoretical views of the nature of vision which had been laid down by the ancients and, for the most part, by mediæval writers as well. Thus, for example, he finally overthrew the old-time doctrine that, in the act of vision, emanations pass out from the eye to the object which the mind desires to investigate, and return with information concerning it.

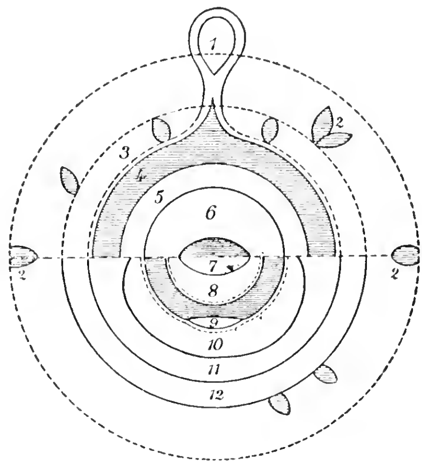
A distinguished Arabian physician of the middle ages was As-Samarqandi. The date of his birth is not known, but he perished in the conquering of Herat by the Tartars A. D. 1222. He wrote "*On the Causes and Symptoms of Diseases*" and "*On the Anatomy of the Eye.*" The latter (which is based on Galen) is given in full in English in the sketch of **As-Samarqandi** in Vol. I of this *Encyclopedia*, and therefore need not be repeated here.

A distinguished Syrian oculist, of Hama, who flourished in the latter half of the 13th century, and who wrote an important work on ophthalmology, was Salah ad-din ibn Jusuf al-kahhal bi-Hamat. The book, which the author declares was composed for the benefit of his own son, and which bears the title, "*The Book, Light of the Eyes and Collection of Divisions,*" is distributed into ten parts, or chapters, the subjects of which are as follows: (1) Definition of the Eye, its Nature, the Anatomy of its Parts, and of the Lids. (2) The Affair of Vision and the Perception of the Object Looked at. (3) The Kinds of Diseases: Their Causes, Treatments and Times, and the Manner of Employing the Medicines, and the Rules which the Physician has to Follow at each Evacuation. (4) Rules for the Preservation of Vision; and also the Diseases of the Lids, and Their Causes and Kinds and Treatments. (5) Diseases of the Corners of the Eyes. (6) Diseases of the Conjunctiva. (7) Diseases of the Cornea. (8) Diseases of the Uvea. (9) Cataract, which occurs in the Front of the Pupil. (10) The

Simpler Remedies for the Eye. "Therewith the work is at an end, if God, the Exalted, will so have it."

The first book of the work is memorable, because it contains (barring possibly, or probably, one) the earliest illustration of the eye which has come down to our day. Following is the picture in question, with the explanation of its various parts:

Hirschberg declares that the illustration is not to be comprehended, except upon these suppositions: (1) the eye has been divided in two



Salah ad-din's Representation of the Eye.

1. The Hollow Nerve; 2. Muscles; 3. The Hard Membrane; 4. The Choroid; 5. The Retina; 6. The Vitreous Humor; 7. The Crystal; 8. The Arachnoid Membrane; 9. The Egg-White Fluid; 10. The Choroid (Text, Cornea); 11. The Hard Membrane (Text, Choroid); 12. The Conjunctiva.

planes; (2) the part that is here represented is the posterior-inferior quadrant resulting from the two-fold section.

It is highly interesting to know, further, that this earliest extant illustration of the eye, is still to some extent in use among Arabian ophthalmographers. Truly, as has been said, "the Arabs are still in the middle ages."

The second book of the work is also memorable because therein, and in no other writing of the Arabic middle ages, appear a number of geometric illustrations of the various theories of vision at that time prevalent. A number of these diagrams were, however, taken from Euclid's "*Optics*."

A distinguished Arabian ophthalmologist and contemporary of Salah ad din, was Halifa b. Abil-Mahasan, who practised at Aleppo. Concerning the man himself we know almost nothing; his one writing,

however, entitled "*The Book of Sufficiency in Ophthalmology*," is still extant, and is worthy of note for the following reasons: (1) It provides at the outset a list of Arabian ophthalmologists and ophthalmologies, and, as Halifa was one of the latest of the Saracenic writers on the eye, the list, of course, is just about complete, so far, at all events, as concerns the more important writers and books. (2) It contains a very early, perhaps the very earliest, *scientific* illustration of the eye which has come down to our day. (3) It contains a series of pictures of the various instruments which, in Halifa's time, were employed in ocular surgery, together with a running commentary on those instruments. (4) The book itself is an excellent résumé of Arabian ophthalmology, as this existed about the close of the Saracenic period. For a fuller consideration of this book, see, herein, **Halifa**.

The latest of Arabian ophthalmologists was As-Sadili. He flourished in the second half of the 14th century, and wrote the last of Arabian text-books on the eye. This work, which bears the somewhat tautologic title, "*Oculistic Aids for Diseases of the Visual Apparatus*," is divided into five chief parts, in each of which "theory as well as practice" is given its appropriate share of attention. The first division treats of the necessity for the functions of the eyes, and of the anatomy of the organ in question; the second, of general medical, as well as oculistic, principles; the third is devoted to such diseases of the eye as are perceptible to the senses, their symptoms and their treatment; the fourth, so far as possible, to ocular diseases not perceptible to the senses; while the final chapter discusses the names, nature, and values of general as well as ophthalmic medicines.

Especially interesting in the fourth section of the first division of this book is the exposition of the three theories at that time held regarding the nature of vision. These theories were: (1) The visual object sends in something to the eye. (2) From the eye emanates perceptive power outwards to the object. (3) Emanations take place from both the object and the eye, and then commingle somewhere between the two. As-Sadili then concludes that, "The third of these views is correct, and comes close to the truth that the air surrounding us, when it is clear and shining, becomes as it were an organ for vision and continues the activity of the hollow nerves in relation to the brain." He was therefore not a pupil of Alhazen, and had profited nothing by him.

Also interesting is the fact that, in this book, the first brief attempt in all scientific history, excepting that of Aristotle only, is made toward a comparative anatomy and physiology of the eye. It constitutes the

sixth division of the first "Part" of the book, but was fully considered in As-Sadili's sketch, and therefore need not be repeated here.

So ends our history of the Saracenic middle ages, and, on the whole, the showing of the Arabian ophthalmologists is more than merely creditable. The discovery by Rhazes of the pupillary light-reflex, the invention by Ammar of the suction method for cataract, the composition of the earliest special work on ophthalmology in any land or clime by Ali ben Isa, the staggering optical discoveries of Alhazen, which have formed the ground on which all modern geometric and physiologic optics have been based, the achievements of Halifa in ophthalmic iconography and those of As-Sadili in comparative ophthalmic anatomy and physiology: all these things, taken together, establish a monument to Saracenic industry and genius which can never be forgotten. And all these memorable matters are wholly in addition to the greater matter still that these, our dusky brethren, kept alight the torch of general learning for half a thousand years.

At the end of which time they passed it on to Western Europe. So now we come to consider

C. THE WESTERN MIDDLE AGES.

First of all, we should note that the second of the nightmares with which the world was visited in the course of its thousand years of sleep, had now held sway. The first of the horrible dreams, of course, was the Arabian invasion, already discussed. The Arabians had only been expelled from non-Hispanian Europe, and their grip on Northern Africa, Egypt, Syria, Babylonia, Persia, and Northern India grew ever tighter. For four or five hundred years, however, the strictly Saracenic Caliphs governed their various peoples with a certain degree of intelligence and liberality. But about the year 1050 the Seljukian Turks, a tribe of warlike Tartars who had been converted to Islam, but who, by their very nature, were cruel beyond belief, came down upon the Arabic Saracens like wolves on sheep, and conquered almost all of them. Then began, beneath the Turkish rule, an extended series of the most horrible persecutions both of Christian citizens and Christian pilgrims, or palmers, especially in the Holy Land of Palestine. A maniacal wave of religious frenzy thereupon arose in Western Europe, especially as a result of the fervid preaching of a fanatic, Peter the Hermit, the result being The Crusades—the second of the terrible nightmares. This incubus endured from 1096 till 1272, two hundred years. We need not here describe this period in detail, but wish to remind the reader merely that it came in eight horrible stages.

The first four crusades are called, as everybody knows, the Principal Crusades, the second four, the Minor Crusades. There were also a number of other expeditions, the wildest of all perhaps, The Children's Crusade, having been instituted by a French boy of twelve, and participated in by children exclusively. The most of these children were lost on the Mediterranean. Many were sold as slaves in Tunis, Alexandria, and other Mohammedan slave markets. In the various crusades millions of lives were lost, in addition to untold treasure, while the moral degradation of Europe, which had already come as the result of the debasing feudal system, was still further intensified. There was, however, one single, most excellent result of the second of the mediæval nightmares: the sleeper was made to awaken, or at least to slumber uneasily—a condition in which awakening more readily occurs. In other words, the travel in various lands began to liberalize the minds of the soldiers of the cross—an effect which soon was spread throughout all Western Europe.

Even before the crusades a little of Arabian learning had begun to filter to the West—through the mind of a celebrated monk, Constantinus Africanus. Born at Carthage in 1018, this remarkable man traveled extensively, studied for a long time in the School of the Mosque at Cairo, for a brief period taught in Salerno at the University, and finally retired to the Monastery of Monte Cassino, in Campania (not far from Salerno), where he died in 1085 (1087?). He was a man of enormous influence until the close of the Middle Ages. Thus, he was called by many mediæval writers "Orientis et Occidentis Doctor." He translated (to some extent recasting) into mediæval Latin a very large number of works from the Arabic. Among these was a "*Liber de Oculis*," ostensibly a volume of his own composition, but really a translation of various passages from Hunain.

Constantinus will always be remembered by ophthalmologists, not only because of the introduction by him of Arabian learning into the West, but also because of his invention of the word "cataract." This term occurs for the very first time in the title of the 27th chapter of the little book, "*De Oculis*," just mentioned. The Arabic term was either "ma" (= water) or "al-ma an-nazil fil ain" (= the water that runs down into the eye); the Latin, as already stated, was "suffusio," the Greek, "hypochyma."

A Salernitan oculist of the 12th century, who seems to have been a man of importance in his day, but concerning whom we have but little knowledge, was Master Zacharias. He studied for three years at Constantinople with Theophilus, who seems to have been a body-physician to the Emperor Emmanuel. Returning to Salerno, he practised and

taught there, and also wrote a brief work entitled, "*Liber Oculorum, qui Vocatur Sisilaccra, id est Secreta Secretorum.*"

This little volume (as obscurely written as it is brief) falls into three "Books": The first of these treats of ocular diagnosis and the underlying principles of oculistic treatment; the second, of the causes of eye-diseases and the special therapy of each disease; the third is a badly arranged collection of prescriptions.

A more important oculist by far was Benevenutus Grapheus, of Jerusalem, who in Provençal is called Ben Vengut de Salern. He flourished in the middle of the 12th century, studied with Arabian masters in Jerusalem, was widely known throughout the West as a cataract depressor, or coucher, and composed a book entitled "*Practica Oculorum.*" This is all we really know of Benevenutus Grapheus of Jerusalem. His work (which seems to have been written in Hebrew) is a compilation from both the Arabians and the Greeks, and contains almost nothing which, even in his day, was new. His work was soon translated into Latin, then into Provençal, Old French, and Old English. The work is very accessible, if any care to read it, because of the Latin edition given out by Dr. Berger and Auracher at München in 1884 and 1886, and the Provençal by Pansier and Laborde at Paris, in 1901, with the title "*Le Compendil pour la Douleur et Maladie des Yeulx qui a Esté Ordonné par Bienvenu Graffe,*" etc.

The next of the Western oculists was a very distinguished physician, who was called Peter the Spaniard (although he was really a Portuguese) and who was afterwards Pope John XXI.[91] Peter the Spaniard, or Portuguese, flourished in the 13th century, and was very prolific as a writer. He wrote an ophthalmic work, entitled "*Liber de Oculis,*" which would seem to be properly designated "*Breviarium Magistri Petri Hyspani de Egritudinibus Oculorum et Curis.*" In addition to a brief introduction, the work consists of four parts. Of these, the first is a condensation from Constantinus Africanus; the second, "Tractatus Mirabilis Aquarum Quem Composuit Petrus Hyspanus:" the third, a literal copy of the first "Book" of the "*Liber Oculorum*" of Master Zacharias; while the fourth is a collection of prescriptions.[92]

The next of the Western writers on the eye was Arnold of Villanova (1235-1313), a famous physician in general, but a very poor oculist.

[91] "That a man who was as distinguished in medicine as Peter of Spain should have been elected Pope is the best possible proof that there was no opposition between science and religion during the 13th century."—Walsh, "*The Popes and Science,*" p. 208.

[92] For a detailed discussion of Petrus Hispanus see Petella, "A Critical and Historical Knowledge of Ophthalmology by a Philosopher Physician, who Became Pope," *Janus*, Amsterdam, 1897-1898.

His only ophthalmic composition "*Libellus Regiminis de Confortatione Visus,*" written at the request of Pope Clement V, possesses but little value. It treats merely of ocular hygiene, and is nothing but a compilation, chiefly from the Arab, Mesne.

And now we come to the only personage of the Western middle ages, who can be at all compared with Alhazen, that most remarkable genius of the Arabians. The man in mind, of course, is Roger Bacon, the first in history to mention the use of lenses as a means of assisting the sight. This distinguished natural historian, chemist, physicist, mechanician, mathematician, and philosopher (worthily, if unofficially, entitled "Doctor Mirabilis") was born in 1214, near Ilchester, Somersetshire, England, and died about 1294. His life we have given with probably sufficient detail in his sketch in this *Encyclopedia.*

The immortal passage on lenses as a means of assisting the sight occurs in the *Opus Majus,* at page 352 of the London edition of 1733, and runs as follows: "If indeed a man observes letters and other minute objects through the medium of a crystal, either of glass or of other transparent material, set down upon the letters, and if it be the lesser portion of a sphere, whose convexity is towards the eye, and the eye be in the air, far better he sees the letters, and they appear to him larger. For, according to the truth of the fifth law of a spherical medium, whatever is below it and this side its center, and whose convexity is toward the eye, all things co-operate for size, because the angle is larger under which it is seen, and the image is larger, and the place of the image is nearer, because the object is between the eye and the center, and, therefore, this instrument is useful to the aged and to those having weak eyes. For they can see any letter, howsoever small, of a sufficient magnitude. If indeed it be the major portion of a sphere, or the half, then, according to the sixth law, there arrives the enlargement of the angle and an enlargement of the image, but the propinquity is wanting, because the place of the image is beyond the object to the degree that the center of the sphere is between the eye and the thing seen, and therefore this instrument has no value, except as it may be a minor portion of a sphere, and instruments of plane crystalline bodies according to the first law of plane surfaces and instruments of concave spheres according to the first and second law of spheres can do likewise. But, among all, the minor portion of a sphere whose convexity is toward the eye, exhibits the size more plainly, because of three reasons, at the same time conjoined, as I have already indicated."

Aside from the fact that, in this passage, the great philosopher has committed a number of errors, each and all of which could easily be

pointed out today by Macaulay's schoolboy (if he be still in existence) there remains the further and unforgettable fact that, in this self-same bit of exposition, it was observed, for the very first time in recorded history, that those who are old, or weak-of-sight from other causes, can be given material assistance by means of the convex lens.

The history of spectacles and eyeglasses has been given already in this *Encyclopedia*, but, for the sake of continuity in this article, we may here present the following extremely condensed statement of facts with reference to this important matter:

1. Lenses of any sort or kind, as aids to vision, were wholly unknown to antiquity. The often cited passage from Suetonius about Nero and his emerald,[93] is irrelevant absolutely, referring as it does not to a lens of any sort, but to a concave mirror.

2. Lenses were certainly not introduced (the contrary has carelessly been alleged) into Europe from China. The earliest citations in this regard, to writings or affairs Chinese, date back to a time much later than the passage above-translated from Bacon.

3. The very first mention in history of the employment of lenses as a means of assisting the sight is that of Bacon, as rendered above.

4. The first inventor of *spectacles* is not known.

5. The *re*-inventor of spectacles was Alexander de Spina, who died in 1313. See **Alexander de Spina**.

6. Salvino Armati had nothing to do with the matter, though often asserted to have been the first inventor of spectacles. See **Armati, Salvino**.

7. By the middle of the 14th century, convex lenses and spectacle frames were in general use.

8. Convex lenses began to be employed about the beginning of the 16th century. Pope Leo X, for example, is known to have worn a pair in 1517.

9. Bi-focal spectacles were invented by Benjamin Franklin.

10. Cylindrical lenses began to be employed about the beginning of the 19th century.

11. Near the middle of the 19th century, owing chiefly to the efforts of Arlt, the fitting of glasses was taken up by ophthalmologists.

The greatest surgeon of the middle ages, Guy de Chauliac, who lived a little after Bacon, is also possessed of a certain ophthalmologic interest. Born about 1300 at the village of Chauliac, or Cauliaco, on the borders of Auvergne, France, he was educated at Montpellier, Bologna, and Paris, he practised at Lyons for a long time, finally becoming

[93] See, in this article, *supra*, under the discussion of Pliny.

physician-in-ordinary to three successive popes—Clement VI, Innocent VI, and Urban V at Avignon. He died in 1638.

Guy's greatest work is his "*Chirurgiae Tractatus Septem, cum Antidotario*" or "*Collectorium Artis Chirurgicalis Medicinae,*" better known, however, as "*Chirurgia Magna,*" because of another and smaller work by the same writer, entitled "*Chirurgia Parva.*" The "*Chirurgia Magna,*" a marvel of learning and of literary style, was *facile princeps* of all the works on surgery throughout Western Europe for many centuries.

De Chauliac's writings on ophthalmology, so far as extant, are comprised in the second part of the Seventh Division of his "*Chirurgia Magna.*" Opinions differ greatly as to the value of these 31 folio pages. Pansier declares them to be an "uninteresting compilation;" Hirschberg, on the contrary, says regarding them: "I find this treatise better than almost any other which the European middle ages have bequeathed te us in our special branch; at all events, it was, in its day, more practical and instructive." The truth, in this instance, is probably with Pansier, for little that is really original appears in the book. The following passage, however, on cataract and "gutta serena," is memorable, as exhibiting, in a style at once terse and clear, the mediæval views on cataract and amaurosis: "Cataract is a cuticular blemish in the eye, in front of the pupil, which disturbs the sight. It consists of a foreign humor, which gradually descends into the eye, and hardens in consequence of the eye's coldness. Whether this humor collects between the cornea and the iris (as Jesus proves) or between the aqueous humor and the crystalline lens (as Galen pretends in the tenth book "On the Use of the Parts") does not interest me just now. The first stage is called 'Illusion of the Sight;' the second, 'The Falling of the Water,' or, sometimes, 'gutta;' the third, or last, stage, 'Cataract,' because it obstructs the visual power as the sluice of the mill, and as the waterfall from the sky obstructs the sun."

For a fuller consideration of the ophthalmography of Guy de Chauliac, the writer is referred to his sketch in this *Encyclopedia.*

The first in history to employ the magnet, or lodestone, for the extraction of metallic particles from the eye was Hieronymous Brunschwyck, whose name was also written Braunschweig, Brunschwig, Brunswick, and Brunswyck. Born about 1424, he is said by Malgaigne to have lived 110 years. He studied at Bologna, Padua and Paris, and became a very distinguished surgeon.

The ancient Egyptians and the Greeks knew about the lodestone and its iron-attracting properties, but employed the substance in ophthalmology only as a casual ingredient in eye-salves.

The physicians of ancient India, as recorded by Susruta (about the beginning of the Christian Era) in his Ayur-Veda, made use of the magnet for the purpose of extracting foreign substances which had entered the body *via* a wound in the skin, but, so far as known, never employed the magnet in ophthalmology.

Then, for about a millenary and a half, there was not the slightest progress in the use of the magnet medically. The long period of torpor, however, was broken into at last by Brunschwyck, who, as stated, for the very first time in history, removed a foreign body from the eye by means of the magnet. The passage in which this notable event finds earliest mention is Brunschwyck's own book, entitled "*Dis ist das Buch der Cirurgia, Hantwirkung der Wundarrtznei.*" This book, written in 1462, was not published till 1497. The passage in question runs as follows: "Ob es aber wer von eysen figelot (Feilicht) so sper das Aug etwas auff unnd heb darfür ain magneten stain der Zëuhet das ansich."

We may add, for the sake of completeness, the following: Fabricius Hildanus, in 1624, repeated the performance of Brunschwyck.

That Nikolaus Meyer, in 1842, was the first to remove a foreign body by means of a magnet applied through a wound in the sclera—in other words, to remove by the magnet-operation a foreign body from the ocular interior.

That, in 1859, Dixon of London first made a surgical incision through the ocular tunics for the purpose of performing the magnet-operation.

That the first to insert the tip of the magnet into the vitreous was McKeown, of Belfast, Ireland, in 1874.

That, finally, in 1875, Julius Hirschberg invented the electro-magnet for the removal of attractable substances from the eye.

The Western middle ages came to a close, ophthalmologically speaking, with Leonardo da Vinci, a famous Italian painter, sculptor, architect, musician, mechanician, engineer, optician and physiologist, whose writings on the eye and light are of interest to every ophthalmologist even at the present day. He, in fact, it was who both produced the Monna Lisa, and who also discovered that the essential organ of vision was not, as had been supposed until his time, the crystalline lens, but the retina He is also said to have been the first to recognize the principle of the camera obscura as well as to apply this principle in explaining the optical action of the eye—in both of which matters, however, his priority is disputed. He was certainly the first to show that the moon shines with light reflected from the sun. He was born in 1452, the illegitimate son of a Florentine lawyer, and died in 1519,

the greatest scientist, as well as artist, of his day. His life I have already given with sufficient fullness in his sketch, and therefore now proceed to discuss such portions of his work as have an especial interest for ophthalmologists.

Very unfortunately, all of Leonardo's observations on optics are the merest memoranda, widely scattered in various writings, which themselves are only extant in the most disorderly form conceivable. Moreover, they are almost wholly devoid of connection either with

Leonardo da Vinci.

each other or with any other matter, or matters, in his writings, and, besides, are written in a style of great obscurity. To these three facts are chiefly to be attributed the great variety of opinions as to what Leonardo did and what he did not discover. Referring the reader, then, for detailed discussions of the great man's achievements to Elsässer's "D. Bedeūtūng Leonarda da Vinci's f. die Exakten Naturwissenschaften" (*Preūss. Jahrbücher*, 97, Bd., Berlin, 1899), Werner's "D. Funktion des Auges bei Leonardo da Vinci" (*Zeitschr. für Mathematik u. Physik*. 45 Bd., Leipzig, 1900) and the same writer's "Zur Physik Leonardo da Vinci's" (Diss., Magdeburg, 1910), we herewith do our best to summarize in a simple and intelligible manner such achievements of this man as would appear to be of especial interest to ophthalmologists.

A passage which possesses considerable attraction, because, at first

view, it seems to announce the undulatory theory of light, is as follows: "Just as a stone thrown into water makes of itself a central point and begets various circles, and just as sound expands in circular forms through the atmosphere, in the same way every object to be found in a luminous atmosphere sends out its species [images, forms, masks] in a circular manner, fills the surrounding portion of the air with its innumerable pictures and the whole [of itself] appears everywhere and in each and every place." A moment's reflection, however, is enough to convince us that this is simply the old-time mask, or image, theory of light of Democritus of Abdera.[94] The world was still to wait for Huygens who, in 1678, declared the fundamental principles of the wave theory of light. The fact is that Leonardo, in the present passage, far from being in advance of Huygens, was really far in the rear of Alhazen. However, in various other passages, he seems to have comprehended fully Alhazen's views and to have put them to noble uses.

Concerning the question as to whether or not Leonardo was first to discover the principle of the camera obscura, and especially as to whether he was the first to apply this principle in the explanation of the optics of the eye, there are many and widely-diverging views. The passage on which Venturi[95] (who assigns the credit for the camera obscura to Leonardo) mainly relies, is as follows: "Experience as to the question how objects send their pictures into the eye and its watery humor, reveals itself when the images of illuminated objects, enter through a small aperture into a dark dwelling. You will then catch these images on white paper, which is set up not far from the opening in the dwelling mentioned, and on this paper will behold all the mentioned objects with their proper forms and colors, but they will be smaller and the uppermost will be turned downward on account of the mentioned intersection [of the rays]. When the images come from a place illuminated by the sun, they will look as if painted on the paper. The latter should be very thin and looked at from the rear side; the perforation should be made in a small, very thin iron plate. In a similar manner does the ray act within the pupil."

Elsässer takes the ground that Leonardo did not mean precisely what, on first consideration, he would seem to have meant by this passage.

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[94] The fundamental differences between the two theories were, of course: (1) The transmission of rays, not images. (This was the theory of Alhazen, foreshadowed by Aristotle.) (2) The transverse character of the rays, not to the source, but to the direction of the ray—in which respect it differs absolutely from the sound wave.

[95] Essai sur les ouvrages physico-mathematique de Léonardo da Vinci, Paris, 1797.

In any case, it appears to the present writer to be certain (1) That Leonardo did not think that the image in the back of the eye was inverted. He believed, indeed, that inversion did actually occur—i. e., within (or else immediately behind)[96] the pupil, precisely as was the case in the camera obscura, but he also believed that, by a second intersection of the rays the image was restored, at the back of the eye, to its original, i. e., upright, position. "The eye, which receives through a very small opening the rays of objects which are situated on the farther side of the opening, receive them always in an inverted sense, and nevertheless the visual pneuma perceives them on the spot where they really are. That arises in this way, that the rays mentioned pass through the middle point of the crystalline body, which lies in the center of the eye, and then diverge toward the posterior surface of this body. On this rear surface the rays direct themselves toward the object which has called them into existence, and from that spot are conducted by the perceptive organ (optic nerve) to the *sensus communis* which passes judgment on them. That this is true is proved in the following manner: Let a fine opening be made with the point of a needle in paper, and then let objects on the opposite side of the paper be viewed through the perforation. If, now, the needle is moved between eye and paper straight from above downward, then the motion of the needle will appear on the opposite side of the opening in a direction contrary to that of its real motion. The reason is this, that when the needle between paper and eye touches the highest rays, it at the same time covers the lowest on the opposite side of the paper; and when the needle passes downward, it comes finally to the lowest line on this side of the paper, which is, at the same time, the highest line on the distal side of the paper."[97]

(2) Leonardo did not think that the image (after its supplementary, or correctional, refraction, falls upon the retina, but either on the posterior surface of the crystalline lens or else on the ocular end of the optic nerve—i. e., on what today we call the papilla.

(3) At all events, he was vastly in advance of his predecessors, all of whom had believed that the essential organ of vision was the lens,

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[96] "As the pupil enlarges, the point of intersection of the rays recedes farther and farther into the eye, but lies nevertheless always in front of the crystalline body." This body Leonardo believed was placed in the center of the eye, the so-called "cataract-space" intervening between this structure and the iris. Sometimes, however, in his drawings, he exhibits the rays as refracted at the anterior surface of the cornea and intersecting at the center of its curvature.

[97] As pointed out by Elsässer, the same experiment, described in the same way, is later to be found in Scheiner's "*Oculus, hoc est Fundamentum Opticum*," Pars II, Experientia 2, "without one's being able to suppose that the latter had known anything of the earlier experiments of Leonardo."

that in the lens the image lay, and that, in that structure, it was seized upon, or seen, by the retina, whose most forward fibres were supposed to be attached to the lens periphery.

So ends the middle ages, ophthalmologically speaking.

And now, at the expense of a slight amount of double repetition, it will pay us very abundantly to turn and review the ground which we have covered since the beginning of our work.

Ophthalmology we find appearing in Babylonia first of all. There, in a most suggestive manner, it makes its first appearance in the pages of a law book, the Code of Hammurabi. It is also seen in the charms and incantations of the priests. It next appears in Egypt, where, too, it is mixed with magic, with theurgy, and with every sort and kind of superstition. After that we find it in the land of logical thinking—Greece. Here it is largely separated from the old-time superstition by the Father of scientific medicine—Hippocrates, who has been prepared for by the Asclepiadæ and by Greek philosophy. Then comparative ophthalmology is added unto it by Aristotle. Next it occurs in the pages of the scientific Celsus, a Roman who has sufficiently forgotten his racial prejudices to become enamored of the healing art. And in Celsus's work we find that the surgery of our branch is much more highly developed than in the *Corpus Hippocraticum*—a fact that is almost certainly due to the (now lost) contributions of the school at Alexandria, a school which has come into existence and flourished abundantly between the time of Hippocrates and that of his Roman disciple.

Then we linger for awhile on the antiquated foolishness of dear old Pliny, who tells us so much of ancient life and ways and so little of scientific medicine. After Pliny, Rufus, the greatest anatomist of antiquity, who discovers the decussation of the optic nerves and the capsule of the crystalline lens. Then we come to Galen, who adds so much to the ancient optics and so little to the modern; who develops, however, the subjects of ocular anatomy and physiology to such a degree that they simply remain in nearly a stationary condition for sixteen hundred years; and whose ocular pathology, therapy and surgery, although surpassed, at the beginning of the middle ages, by those of Aëtius of Amida, are better by far than those of Hippocrates or Celsus.

At the outset of the middle ages we divide the period, for convenience, into the Eastern, or Byzantine, the Saracenic, and the Western, or Later, middle ages. Then, at the beginning of the Eastern period, we find the tremendous compilations of Aëtius of Amida. These, as we see, are lacking completely in the very important subject of optics,

and are also defective to a certain extent in that of surgery also; and yet they are far more thorough and specific in therapy and pathology than the works of Galen have been—so thorough, in fact, that they stand almost unaltered, except in slight particulars, till the middle of the 17th century. After Aëtius we reach another great compiler, Paulus of Ægina, who, however, excels the former writer in the matter of surgery only.

Then the Saracens. The pupillary reflex is discovered by Rhazes, the suction operation is invented by Ammar and the earliest special work on ophthalmology is written by Ali ben Isa. The revolutionary optical discoveries of Alhazen are next in order, displacing the views of all the old philosophers, as well as those of Galen. Light is discovered to consist not of forms, or pictures, or masks, of objects, but of radiant energy; and, at that, not of rays which pass, antennæ-like, from the eye in order to feel of the object, but which run from the object into the eye. Then Halifa, with ophthalmic iconography, and As-Sadili with a number of improvements in comparative ophthalmology.

The Western middle ages, finally, gives us that inestimable blessing to mankind, spectacles, invented, or at least discovered, or re-discovered, by Bacon; as well as the camera obscura (and the application of its principles to the human eye) for which we are indebted to Leonardo.

Such as been the sum and substance of the progress made in the field of ophthalmology till the close of the middle ages. In other words, we are ready now to witness the Fourth Act of our play, which deals with the modern period, or age, in Europe. America, as the reader will no doubt remember, was to be reserved for the fifth and final action of the great ophthalmologic drama.

IV.—THE MODERN PERIOD—EUROPE.

Thus much space we have given to antiquity and to the middle ages, not merely out of love for the olden, far-off things, but chiefly from a frank recognition of the fact that these two stretches of time (in ophthalmology) are the hardest for a modern reader to understand. Therefore the more of exposition did they need. The nearer we come to the present day, in other words, the more we are likely to deal with inventions or discoveries that are still in a fair condition of credit or indeed in daily use. Thus, the 19th century view that the essence of glaucoma consists of a rise in the intraocular tension is still believed, still is taught, and therefore requires but little explanation for a 20th

century reader. The humoral theory of disease, however, such as was vigorously promulgated by old Hippocrates and which lasted for many centuries, is now extinct and can only be understood as the result of considerable explanation. We may, therefore, with perfect justification, proceed to mend our pace a little as we pass through the modern period.

First of all, perhaps, we had better epitomize the condition of science in general at the beginning of the modern age. In the course of the mediaeval period, somehow, somewhere, and by a person, or persons, unknown, gunpowder had been invented, with all its far-reaching and devilish consequences. In a similar vague, mysterious manner and with similarly widely ramifying results, the mariner's compass and the astrolabe had been devised. Paper had been invented in the 10th century, the very darkest days of the middle ages.[98] The Arabs had contrived the figures which are still in use and which, quite properly, are known as "Arabic numerals." They had also invented algebra and other divisions of mathematics. What they had done for the science of chemistry we have had occasion, in another department of our subject, to discuss. Universities and hospitals, in the modern meaning of the words, had here and there been instituted, and had flourished, becoming a permanent portion of the world's eleemosynary and intellectual equipment. The degree of "Doctor," in its present meaning, had begun to be conferred in the 12th century. Clocks were invented in the 14th. Finally, printing, with its boundless consequences, the discovery of America, the revival of learning—in a word, the sleeper was awake.

But what dreams he had had!

The Rip van Winkle of the middle ages (civilized man) had slept for a thousand years, but, like many an intellectual individual, he had had a way of solving difficult problems in his sleep.

The Sixteenth Century.

The last great doer of things in ophthalmology whom we had occasion to discuss in connection with the middle ages was Leonardo da Vinci, whose life extended until 1519, well past the line which is commonly taken to separate the mediaeval period from the modern—1492. Beginning, then, with the 16th century in ophthalmology, we confess to a feeling of shame that, in this century, our specialty improved so

[98] Papyrus and parchment were the writing materials of the ancients, the former being much the earlier in use. From "papyrus" the word "paper" is derived.

little. The 16th century, that wonderful hundred years in politics, in statesmanship, in religion, in literature, in natural science. and even, to a certain degree, in general medicine and surgery, was almost wholly without results in the most important of medical and surgical specialties. The century of the Reformation, of Erasmus, of Bacon and of Shakespeare—each like a god in his own great field of labor—the century of the rise of the Dutch Republic, of abundant and far-reaching discoveries on foreign shores, and more abundant and more far-reaching still in the yet more distant worlds which speckle the infinite distances; the century, in fact, of Copernicus, who found that the earth is by no means the enormous and stationary center of a tributary, and, as it were, a satellite, universe, which circled around it, but merely a tiny, almost infinitesimal, mote in a beam of apparently endless light and matter:—the century of these and of many another man and marvel (or even miracle) which cause the mind of the retrospective beholder to reel and stagger—that century which means so much for every man and woman now alive, produced almost no progress in the science and art of ophthalmology. Considerable advance was scored, to be sure, in general medicine and surgery, as well as in pharmacology and obstetrics. Thus, this was the century of Vesalius, Fallopio, and Eustachius, the three great reformers of anatomy; of Paracelsus, the quack, and yet great reformer of many branches of our art; of Cardanus and Brissot, especial upbuilders of internal medicine; of Paré, the great new force in surgery and obstetrics. All these men were disciples, of course, of old Father Hippocrates. Many others, however, were not such. Thus, many physicians and surgeons believed in cabalism, alchemy, astrology, chiromancy, magical incantations, and what not! Truly there have been, from the earliest ages, two absolutely different streams, or themes, running down in the art of healing, or, we could say with truth, in science of every kind. These two contrasting themes criss-cross, blend, separate, attract, commingle and repel much like the contrasting portions of a two-part fugue. Sometimes we find it difficult to distinguish the one theme from the other, so closely do they run together. Then, again, the separate melodies, if so we may call them, stand out in plain antagonism. Always, however. there is something in the one suggestive of the other, and yet the two are essentially and everlastingly different.

The 16th century made a certain degree of progress in ocular anatomy, physiology, pathology, and treatment. Of each of these branches in its turn.

Anatomy.

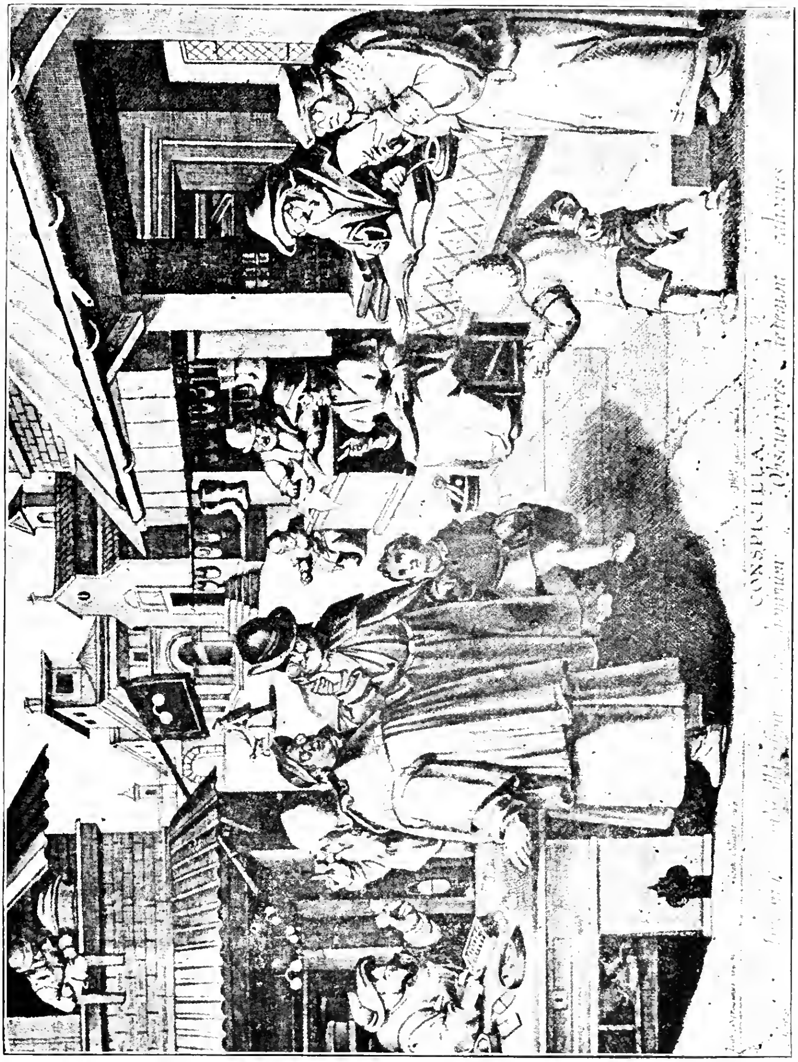
First of all came Giacomo Berengario, of Carpi, who in 1523 first described the conjunctiva correctly, showing that that membrane is not (contrary, it will be remembered, to Galen) an offshoot of the cranial periosteum. The date of Berengario's birth is unknown, but he held the chair of anatomy at Bologna from 1502 till 1527, when he was banished to Ferrara because of his vivisections (and even pederasty!) upon convicts. He discovered the sphenoidal sinus and the tympanic membrane, and made a considerable number of discoveries in anatomy in general. He died in 1550.

The next anatomist of interest to ophthalmologists is Andreas Vesalius (1514-1564) chiefly, however, because of the things which he might have been expected to perform, but which, as a matter of fact, he failed to do. He was born at Brussels, studied at Montpellier and Paris, stole from the gallows a human cadaver,[99] dissected it, and was almost immediately liberated from the trammels of Galenic anatomy, a one-man science which had ruled like a despot for thirteen hundred years. Entering the army, he found himself supplied with sufficient, as well as appropriate, material for dissection. His discoveries in anatomy generally need not detain us here. Of special interest to ourselves, however, we may mention the following "finds": That the anterior humor of the eye does not resemble the white of an egg, but water That the hue of the iris depends not on the nature of the aqueous humor, but on pigment in the iris itself. That the crystalline lens, removed from the eye, produces, like a convex lens of glass, an apparent enlargement of objects seen through it.

It is hard to understand how this great man should have continued much in error with respect to the anatomy of the eye. Yet this, in fact, he did. He continued, for example, to suppose that the crystalline lens is seated in the middle of the eye-ball—a fact well shown by his own illustration of an eye (see figure). He also believed that the optic nerve passed into the eye at a point external to its posterior pole. Finally, he made the great mistake of accepting without question the existence of the so-called choanoides muscle, or retractor bulbi—a muscle which is really found in herbivora, but not in man. The discovery that this structure does not exist in the human species is due to Vesalius's great contemporary, Falloppio.

[99] It will be recalled that Galen did not dissect the cadavers of human beings, but of sheep, oxen, and especially swine. Hence a number of his anatomical errors: such, for example, as that of supposing that the *musculus choanoideus* exists in man.

Gabrielle Falloppio, whose name is also written Fallopia, Falloppia, Fallopio and Fallopius, according to the language, the fashion, and the whim, was born at Modena, Italy, in 1523. He studied at Padua,



A Spectacle Merchant of the Sixteenth Century. By Jean Stradan.

became professor of anatomy at Ferrara, then at Paris, and, finally, at Padua. He was the teacher of Fabricius ab Aequapendente, of whom we shall hear again within this century. Indirectly, through Fabricius, he was a teacher of William Harvey, who discovered the circulation of the blood.

In our especial field, as above suggested, Falloppio is to be remembered because of his having proved that the retractor bulbi muscle (choanoides) does not exist in the human subject. This structure was described as a portion of the human ocular apparatus by Galen (who had really observed such a muscle in cattle, sheep, and other large herbivora) and the error had been continued for more than thirteen hundred years.

Falloppio also described the levator palpebræ superioris muscle, the obliquus superior, the nerve of the latter muscle, the nervus trochlearis, and the hyaloid membrane, which, however, he called *vitrei tunica.*

Physiology.

First and most important of the 16th century physiologists was the churchman and mathematician, Franciscus Maurolycus (1494-1577), who finished the work which had been half-heartedly begun by Leonardo da Vinci. Maurolycus, that is to say, overthrew completely the old Galenic doctrine that the essential organ of vision is the crystalline lens. This he accomplished in his book, "*Photismi de Lumine et Umbra*" (Venice, 1597). Maurolycus also correctly explained for the first time shortsight and farsight, declaring that, in the former abnormality, the ocular lens is curved too strongly, in the latter, however, too weakly.

Maurolycus also shows that, by the refraction of rays of light in a glass sphere an inverted image is produced and declares that for this reason it was that the crystalline body of the eye was not made spherical but lentil-shaped, as, otherwise, the ocular image would have been inverted. Scheiner (born in 1575, just two years before Maurolycus's death) was the first to show that the retinal image is, in fact, inverted. To him we shall come hereafter.

Felix Plater (1536-1614), a professor of medicine at Basel, was the first to declare that the images of objects in the external world (after being distinctly produced by the lens) were received upon the retina. Leonardo had vaguely shadowed forth this doctrine, but believed that the image lay upon the entrance of the optic nerve. He was also not quite sure but that the image was really caught by the posterior surface of the lens. The function of the lens as the image-forming portion of the eye had been correctly determined just a few years prior to Plater's declaration, by the mathematician, Maurolycus, but Maurolycus had not definitely and positively conceived the idea of the screen-like function of the retina. This was done by Plater, who even pro-

ceeded a little further, declaring the retina to be the essential portion of the visual apparatus.

Slowly the science of modern ophthalmology was being put together. "Here a little and there a little."

None of the men, thus far, excepting only the painter, Leonardo da Vinci, had thought of the eye as being in the nature of a camera obscura. Even Leonardo's statements on this point leave us in doubt about his meaning. Not so, however, the pronouncement of Giambattista della Porta, a well known physicist, who was born at Naples in 1538 and who died there in 1615. In the second of his works, "*De Refractione*," occurs the following explicit and unmistakable passage: "As objects illuminated by the sun send their light through a narrow hole in the window-shutter upon a paper placed opposite, exactly so does light, pressing through the hole of the pupil, produce images of objects looked at upon the crystalline lens." Even Porta, however, as will certainly have been noticed, did not *combine* the retina-screen idea with the camera-obscura-eye idea. That honor remained for Kepler, who belongs to the 17th century.

Ocular Pathology and Treatment.

A very early, but unimportant, writer of this century on the pathology and treatment of the eye was Leonhart Fuchs, who was also a distinguished botanist and general practitioner of medicine. He was born in Bavaria in 1501, received the degree of Master of Arts at Ingolstadt in 1521 and that of Doctor of Medicine three years later. He was for a time physician-in-ordinary to the Markgrav George of Brandenburg in Anspach, and was made a nobleman by the Emperor Charles V. In addition to a number of works of a general character, he published in 1538 "*Tabula Oculorum Morbos Comprehendens*," no longer extant, and, in his "*Institutiones Medicae*" a chapter, "Vitiorum Oculi Succincta Explicatio."

A man of slightly more importance was Hieronymus Mercuriali, who was born in 1530, studied at Bologna and Padua, practised in his native town of Forli, and became professor of medicine successively at Padua, Bologna, and Pisa. In addition to numerous works of a general character solely, he wrote *Hier. Mercurialis Forliviensis Medici Celeberrimi de Oculorum et Aurium Affectibus Praelectiones* . . ., Francofurdi, 1591, in which 137 (octavo) pages are devoted to the eye. The work was very authoritative in its day, but was only a re-hash of Galen and the Arabs.

A surgeon of great ability, but of little importance as an ophthal-

mologist, was Jacques Guillemeau (1560-1613), who was body-physician to the King of France, and who published at Paris, in 1585, a work entitled "*Des Maladies de l'Oeil qui sont en Nombre de Cent Treize aux quelles il est Subject.*" The book was a great authority in Germany and England, as well as in France, for a great many years, and formed in fact the sum and substance of Banister's "*One Hundred and Thirteen Diseases of the Eyes and Eyelids*"—the earliest work devoted to diseases of the eye exclusively to appear in English. The

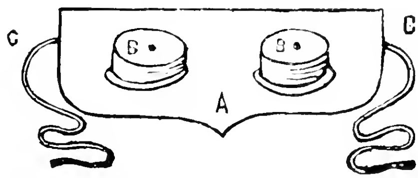
Ambroise Paré. (From the original picture, *L'Ecole de Médicine*, Paris.)

book is based almost wholly on the Arabians and the Greeks, but contains an original operation for lid-coloboma.

"The father of modern surgery," Ambroise Paré, was very much more important as an ophthalmologist than Fuchs, Mercuriali, or Guillemeau. Born in 1509, at Bourg-Hersent, France, he studied at first in a barber-shop, then at the great Hôtel Dieux, in Paris, and, finally, on the field of battle. He is commonly and properly known as the re-inventor of ligation as a means of arresting hemorrhage, but he also invented staphyloplasty and bronchotomy, and was probably the first to perform excision of loose cartilages in joints. He also re-invented trusses, herniotomy for strangulated hernia, and the figure-of-eight suture for hairlip.

Paré invented a speculum oculi, which was truly an improvement over those of all his predecessors. For strabismus he recommended the old-time mask of Paulus of Ægina, as well as spectacles of horn with a hole in each disc.

Paré did not really invent the artificial eye, though often declared to have done so. The history of the *prothesis oculi* is, in fact, very briefly, as follows: The ancient Egyptians placed artificial eyes in mummies, but never in the heads of living people. The ancient Greeks



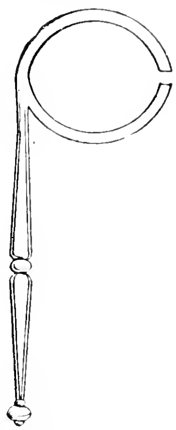
Strabismus Mask, or Spectacles, Employed by Ambroise Paré.

and Romans made use of a similar affair in statues, the person who made or sold such eyes being called *ocularinrius* (not *ocularius*, which meant "oculist"). In the Jerusalem Talmud, Nedar, IX, is a passage which, apparently, refers to the artificial eye, but which is often said by competent authority to be either a corrupted, or an interpolated, passage. Finally, somebody (nobody now knows who) invented the modern *prothesis oculi*, and this affair the "Father of modern surgery," Ambroise Paré, did much, no doubt, to render popular.

The century closed with a greater ophthalmologist than Ambroise Paré—the Saxon, Georg Bartisch, who is called, and properly, the "Father of modern ophthalmology." Bartisch was born at Königsbrück, a village near Dresden, in 1535. He was not a product of the schools, but simply a genius. He never acquired a settled residence, but, after the fashion of the time, went strolling round in many lands, searching for practice. In 1588 he became court oculist to the Elector of Saxony—a position, however, which seems to have fixed him to no definite abode.

In addition to a work on cutting for stone, he wrote the famous "*Ophthalmodouleia das ist Augendienst*," the first ophthalmic textbook in the German language and a priceless heritage of the human race. On the title-page we read (translating, of course): "Ophthalmodouleia, which is Augendienst. New and well-grounded account of causes and knowledge of all imperfections, diseases and infirmities of the eyes, and of the sight, how one in the beginning meets, hinders and guards against all such with appropriate remedies. Also, how one should handle, cure, and drive away all such infirmities with med-

icines, instruments, and skill. With beautiful anatomical figures both of the head and of the eyes, as well as of the aforesaid diseases and infirmities, and also of all instruments and vessels belonging to and serviceable for the cure of such eyes. Also, of artificial preparations, purgations, calcinations, distillations of much applicable material, necessary and useful for the medication of the eyes. Together with a



Ambroise Paré's Ocular Speculum.

short extract from a few testimonials from persons to whom (through God's help) such treatments have assisted in the diseases of the eyes and the sight, which extract is to be found next after the Introduction. . . .

"To all needful physicians, true-hearted fathers of families, and to the especial persons who are laden and afflicted with infirmities, diseases and defects of the eyes and of the sight, or who have to guard against such things, for the comfort, the service and the welfare of such, composed and written by

Georg Bartisch of Königsbrück, Citizen, Oculist, Cutting and Surgical Doctor in the old electoral city of Dresden.

The like has never appeared before this year 1583.

With the Roman, imperial Majesty, favoring freedom for ten years not to be reprinted."

Not only was Bartisch the first to write an ophthalmic text-book in the German language, he was also the first to remove an eye *in toto* from the living human subject. Here is his account of one of his complete removals of the eye-ball. "In case, however, any person's eye

projects extremely far forward *(egressio oculi)*, of which I have seen many and taken many out, and if it is large, hideous, and detestable, and cannot be covered up or hidden, as is to be seen by the following figure; and the person would be gladly loose and free from this, then I do to him as follows: . . . Take, from the instruments here drawn, one which seems to thy hand best and most convenient, whose figure is shown herein, which must be prepared until it is as sharp as any razor can be; press it into a groove under the upper lid, however very close to the bone and on the skull-cap to the very backmost ground, turn then quickly and dexterously the entire eye, especially so that it may be emptied out and made loose on the hinder place in all parts, very fine and close around on the skull-cap and the bones, in order that the corrupted material, the bad humors, veins and nerves may be brought out and away completely at all places. Yet every one ought, who goes about this, to see to it industriously in advance that he does not injure the upper and the lower lid, so that it may not afterwards heal hideously and hatefully.

"When such a proceeding, however, has been well performed, and the eye has been taken out; then let not the patient bleed long, but bind him up quickly, and use at the first dressing a powder of white vitriol, alum, etc."

Georg Bartisch died in 1607. He had led a long, active and useful life, and moreover, as suggested above, he will ever be known as the first of the long and glorious procession of Teutonic ophthalmographers.

And so the 16th century closed in no ignoble manner after all—that is, with Bartisch. The century in question, however, like all that have ever existed, clear down to the very one in which I write, presents to our view a considerable proportion of anti-Hippocratic, or non-scientific, matter, even in medicine and ophthalmology. Thus, for example, in the very book of Bartisch, a number of chapters are devoted to black magic, to white magic, to sorcery, and so on. We should also mention here that Bartisch was bitterly opposed to the use of spectacles. He had known, he said, of many eyes which had been destroyed by them. Moreover, one sees vastly better when one has nothing at all before the eyes. A person ought rather to employ the right kind of powder or eye-water. Alchemy and astrology still flourished in the 16th century. So, too, did cabalism, chiromancy, and even that folly of all follies, necromancy, or the art of prophesying by means of pretended communications with the dead. And all these isms and ancies were more or less accredited by doctors. The profession, in fact, had left, from time to frequent time, the Sinaitic law of old Hippocrates, and gone dancing like mad round the golden calf of

silly theory and superstition—just, indeed, as still they do, in this, the 20th century—the difference being that we of today do not so readily recognize the quasi-science of the present as the pseudo-science of the past.

The Seventeenth Century.

The 17th century was also a brilliant period in general, but dull in ophthalmology. These hundred years, in other words, were the time (for literature) of Raleigh and of Milton, of Hobbs and of Locke, of Bunyan and of Dryden, and of the authorized translation of the Scriptures. In France there were Corneille, Racine, and Molière, as well as Descartes and Malebranche. Politically, it was the age of the Thirty Years' War, of Gustavus Adolphus, The War of the Palatinate and that of the Spanish Succession, the time of Oliver Cromwell, founder of liberty in England. It was, furthermore, in a scientific way, the time of Sir Isaac Newton, discoverer of the law of gravitation and inventor of the emission, or corpuscular, theory of light; of Galileo, who invented the thermometer and the telescope. This, furthermore, was the age of the rejuvenation of chemistry (which had done but little since the Arabian activity), of the invention of the compound microscope, and of the far-reaching "cell-doctrine." It was also the century of the origin of scientific journals and societies.[1] Medically, it was the time of Sydenham, the Hippocrates of England;[2] of Sylvius, founder of the iatrochemical school, which explained diseases on chemical principles, and of Borelli, founder of the equally famous and absolutely opposing school, the iatromechanical, which "applied the laws of mechanics and of mathematics to the human body," its functions and its diseases. It was, yet again, this crowning age, the time of William Harvey (most marvelous man in modern medicine!), who discovered the circulation of the blood—in the very identical year, by the way, in which the heart of Shakespeare ceased to beat.

Yet, when we turn to ophthalmology, we find but little, to speak relatively, accomplished. There is just one great exception.

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[1] The "Academy degli Lyncei" was founded at Rome in 1603; the "Gesellschaft naturforschender Artzte," at Schweinfurth, Germany, in 1652; "The Royal Society of the Sciences" at London, in 1662; the "Académie des Sciences" (not to be confounded with the "Académie Française"—Richelieu, 1635) at Paris, in 1665.

[2] "Sydenham's model was Hippocrates, upon whom he seems to have formed himself almost exclusively, and whose principles, with some modifications resulting from the condition of knowledge in his day—on the whole only a few—he made his own. In pathology he was, like Hippocrates, a humorist without being a theorist, and he defended himself against those who laid this to his reproach in almost the same words used by Hippocrates"—Baas, "*History of Medicine,*" trans. by Handerson, 1910, p. 505.

The century, that is to say, began with a discovery which really ranks among the greatest, that of the true location of the crystalline lens. Perhaps no farther-reaching or, ultimately, more propulsive discovery was ever made in ophthalmology than this—the work of Fabricius ab Acquapendente, who, in 1600, barely in fact at the threshold of the century, in his work, *De Oculo*, (III, c. 8) shows, in a drawing, the correct position of the lens. A solitary musical note will now and then compel a very large number of sand-grains lying on a membrane to dance about of a sudden and to re-arrange themselves into beautiful designs, perhaps of trees or flowers, or the distant likenesses of human beings. And so it should have been with many facts in ophthalmology, on the publication of this discovery of Fabricius. However, the "fullness of the times," as yet, was lacking. The re-arrangement was deferred.

Fabricius was born in 1537 at Acquapendente, Italy, studied at Padua, and became a pupil of Falleppio. He was also the eminent teacher of William Harvey, who discovered the circulation of the blood. In spite of Fabricius's great discovery (the full importance of which he did not seem to understand himself), this very great man performed the cataract operation but twice or thrice all told, and recommended for this fearful trouble a certain collyrium in an eye-cup. He died in 1624.

A celebrated Dutch apothecary and physician, of importance in ophthalmology, was Fredrik Ruysch. He was first to describe the arteria centralis retinæ, the tunica Ruyschiana, the venæ vorticosæ, and the ciliary nerve. Born at the Hague in 1638, he there became an apothecary in 1661, and received his medical degree at Leyden in 1664. After a number of subordinate positions, he held the chair of legal medicine and botany at the Athenæum. He died in 1731.

In the very same year as Ruysch (1638) was born a German, Heinrich Meibom, also of some, though of less, importance for the anatomy of the eye. In fact he did not really discover the glands which bear his name, for these were known to Galen. However, he did supply the first exact description of these structures. He was born in 1638, taught at Helmstädt, and died in 1700.

William Briggs, of Norwich, England, discoverer of the optic papilla, was born in 1641, became a pupil of Vieussens, superintendent of St. Thomas's Hospital under Charles II, and body-physician to William III. In 1676 he published a work entitled "*Ophthalmographia,*" a work which I have not been able to examine, but which is said to contain the famous description of the optical papilla. Briggs died in 1704.

Most important of all the ocular anatomists of the 17th century was another Dutchman, Anton van Leeuwenhoeck. Born at Delft, Holland, in 1632, he is said to have been the first to employ the microscope on the tissues of the eye. At all events he discovered the layer of rods of the retina, the fibres of the lens and the cornea, and the epithelial layer of the latter membrane. He is also said by some to have discovered the capillary circulation, a performance which, of course, completed the work of Harvey. The weight of authority, however, is in favor of according the honor in question to Malpighi.

The optical advances made in the 16th century by Maurolycus, Plempius, Porta, and Plater, were now successfully continued, chiefly by the great German astronomer, Kepler, and a simple licentiate and notary of Seville, Spain, Daça da Valdes. Of the latter we shall speak first.

Benoist Daça da Valdes was not a physician, or even an apothecary, but only a humble licentiate and notary of the Inquisition at Seville. He published in 1623, a highly practical work, of 100 quarto pages, which is now so rare that even a single copy does not exist in the British Museum. A MS. copy, however, of a French translation is in the possession of the Bibliothèque Nationale, at Paris, and this translation, in 1892, was published at Modena, Italy, by Albertotti *(Manuscritto francesc del secolo XVII riguardante l'uso degli Occhiali)*. The title of the French translation (further translated into English, of course) is as follows: "*The Use of Spectacles for Every Kind of Sight, in which Instruction is Offered for Knowing the Degrees to which the Sight has Failed* . . . Also, at what time one should begin to use spectacles, and how a person may know this matter though absent, together with other important information for the use and preservation of the vision. By Benoist Daça da Valdes, licentiate and notary of the Inquisition in the city of Seville, the whole translated from the Spanish into French, following the copy printed at Seville by Diego Perez, in the year 1623." The work is divided into three parts: On the Nature and Properties of the Eyes; On Remedies for the Sight by Means of Glasses; Dialogues Between Various Persons and a Master Maker of Spectacles. The first division is a kind of protracted eulogy of sight and spectacles. The second, or scientific, portion, is chiefly based on Galen and Aristotle, excepting the optical principles, which, strangely enough, do not go back to Vitellio and Alhazen, but to "Antoine Moreno, licensed cosmograph and his Majesty's professor in the commercial house of the Indies at Seville." This part of the book prescribes the earliest method for determining the strength of lenses, declares for the earliest time in history the value of convex lenses

after the cataract operation (which was always, then, depression) and, finally, provides the following table of lens-strengths for presbyopes at various ages, and for women as well as men:

	Men.	Women.
From 30 to 40 years..............	2 degrees	5 degrees
From 40 to 50 years..............	2.5 "	7 "
From 50 to 60 years..............	3 "	8 "
From 60 to 70 years..............	3.5 "	9 "
From 70 to 80 years..............	4 "	. "
Higher ages	5 to 6 degrees	. "

His reason for assigning stronger lenses to women than to men are: first, that women do more delicate eye-work than do men; second, that they have a weaker sight by nature.

And now we come to Kepler, the second greatest optician of all time, as well as immortal theologian and astronomer. Born at Weil, Würtemberg, Germany, in 1571, he studied the liberal arts at Leonberg and theology at Tübingen. Having turned his attention to the physical sciences, he was appointed in 1594 to the chair of astronomy at Gratz. In 1630 he died at Ratisbon, aged only 59.

The optical discoveries of Johannes Kepler are almost all contained in his "*Ad Vitellionem Paralipomena*" (1604) and "*Dioptrics*" (1610). To be as brief as possible, we may here state, formally, that the following optical facts, either absolute or approximate, were by him expressed either for the very first time, or else for the first time clearly and distinctly.

1. A retinal image consists of as many couples, or pairs, of light-cones (placed base to base at the lens) as there are points in the object looked at.

2. The central point of the retina possesses the sharpest vision.

3. Eccentric vision does not give satisfaction, but merely invites the eye to turn in this or that direction for the purpose of securing a sharper view.

4. It is the vitreous humor which holds the retina taut.

5. The crystalline humor presents behind a hyperbolic surface, in front, a spherical—which produces a better refraction.

6. Every eye possesses a point, externally, of sharpest vision. The bundle of rays which sets out from this point unites in a point again upon the retina. Every object which lies beyond this point appears to be indistinct.

7. Eyes that see far objects plainly, but near ones dimly, are helped by convex lenses.

8. Those, on the other hand, which see far objects dimly, but near ones plainly, are benefited by concave glasses.

9. The convex lenses assist by altering the rays which pass to the eye from near objects in such a manner that they become like to those which proceed from objects more remote.

10. The concave lenses, on the contrary, alter the rays which come from distant objects in such a fashion that they seem to proceed from points that are near at hand.

11. Without the concave lenses, rays which come from a distant point would intersect one another in front of the retina, and, having still farther to proceed, would disperse themselves into a certain breadth, instead of a sharp point.

12. When sunlight shines upon a prism, there arise three kinds of rays: (1) the unchanged; (2) those of the color of the glass; (3) rainbow colored.

13. A plane-sided right-angled prism does not permit the rays falling parallel to a cathetus to pass through.

14. An object looked at through a prism appears to have been moved in the direction of the edge.

15. Every distant point emits rays in all directions. As to the eye, however, or as to any lens, whose diameter is negligibly little in comparison with the distance, the most external of the rays which strike upon the eye or the glass may be regarded as parallel.

16. Of all the rays in any pencil that impinges on a curved surface, only one can be regarded as vertical thereto.

17. Rays proceeding from a near point diverge as they pass toward the pupil of the eye. Of rays proceeding from different points on the same object, however, many necessarily converge as they move toward the eye. One should carefully distinguish between the bundle of rays emitted by a single point, and the different rays sent out by several points.

In addition to establishing all these highly important facts, Kepler also considerably enriched the optical nomenclature. Thus, to him we owe—at least in their optical acceptations—the terms, "prism," "lens," and "meniscus." "Prisma," before his time, meant, simply, "sawing-block;" "lens" meant a "lentil;" and "meniscus," the "half-moon."

Altogether, we may say that, till the time of Helmholtz, no other person did so much for the furtherance of optics, physical or physiological, as did Johannes Kepler.

A lesser man in optics was Bonaventura Cavalieri (1598-1647), the first to furnish a formula solving the problem, How to find the focal distance for parallel rays of light for any convex or concave lens. This formula, which appeared in Cavalieri's "*Exercit. Geomet.*" (Bonon. 1647) was this: $F = \frac{2\, r^1\, r^2}{r^1 + r^2}$. Here, r^1 is the radius of the spherical surface which is toward the parallel rays; r^2 the radius of the remaining surface. The ratio of refraction is assumed to be (from air to glass) 3:2.

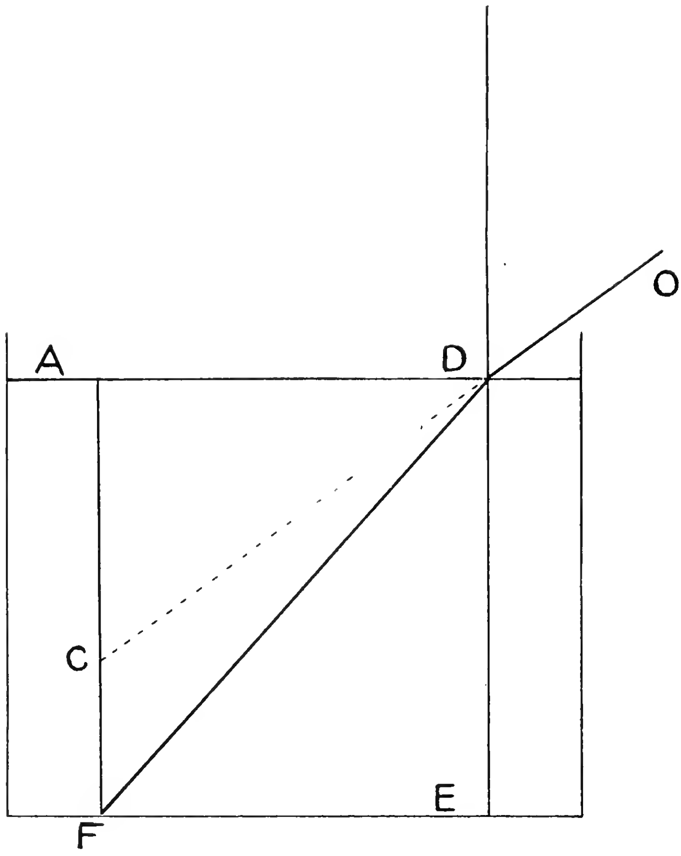
The really first to discover the law of refraction was Willebrord Snell, or Snellius. Born at Leyden in 1591, son of a celebrated professor of mathematics in that place, Rudolph Snellius, he became professor of mechanics at the Leyden University, and died in 1626, aged, therefore, only 35 years. At the time of his death, his views concerning the refraction of light had not been published, but Isaac Voss [3] and Christian Huygens were shown by Snell himself the MS. in which these views were written, and, in especial, his "law of the refraction of light." According to both these high authorities, Snell, and not Descartes, was really first to discover the law of refraction. Also according to Huygens, the law was expressed by Snell at least with substantial accuracy, though not in the same convenient form as that conferred upon it later by Descartes. Here, then, is the law, as reported by Christian Huygens: "If an eye at O believes that it sees an object F (in a denser medium, e. g. water) in the direction OCD, and if FC be imagined as continued vertically to the refracting surface AD, then the real ray of incidence DF bears to the apparent ray CD an unalterable ratio, as long as the refracting substance remains the same. The quantities CD and DF conduct themselves like the cosecants of the angle which the refracted and the entering ray form with the perpendicular of incidence DE. Snell, therefore, expressed his law as follows: For the same media the ratio between the cosecant of the angle of incidence and that of the angle of refraction keeps always the same value."

This law was re-discovered (as some will have it, plagiarized) by René Descartes, in a somewhat altered form—i. e., the sines of the angles in question were compared, instead of their cosecants, and then the law, of course, was simply stated *in reverso*.

René Descartes (L. Renatus Cartesius) was born at La Hay, Touraine, France, March 30, 1596, spent the years from 1612-1616 in study

[3] A fact recorded in his "*De Natura Lucis*" (1662).

at Paris, was then for a number of years engaged in military service in the German War, and then became a traveler. From 1629 he lived in retirement at various places in Holland until his death in 1650. In addition to his re-discovery of the law of light-refraction, Descartes was the author of what is known as the Cartesian theory of the nature



of light—a theory which stands half-way between the corpuscular theory of Sir Isaac Newton (still to be referred to) and the undulatory theory of Christian Huygens. He thought, that is to say, that light-impulses are conducted from the luminous body to the eye "by the propagation of direct motion from one minute particle of subtle matter [corpuscles] to the next, and so on in right lines, till the last of the series affected the eye." He hence believed, almost as a necessary

corollary, that the passage of light through space takes place instantaneously "as a blind man feels with the end of a stick." The production of the different colors he explained by a rotary motion of those particles which art directly on the retina: the rapidest rotary motion of all gives red; the next most rapid, yellow; while blue and green can only occur when the rotary motions are slower than the direct.

The corpuscular theory of light was proposed by the great discoverer of the law of gravitation, Sir Isaac Newton, who also discovered the dispersion of light, the composite nature of white light, and the unequal refrangibility of different colors. He was born near Granthame, England, in 1643, received the degrees of bachelor and master of arts at Trinity College, Cambridge, was made Lucasian professor of mathematics at Cambridge, for a time was a member of Parliament, and, later, the master of the mint, while serving in which capacity he died, of a complication of diseases, in 1727, aged 84. Newton's corpuscular, which is also called the "emission" theory of light, declares, or rather hypothecates, that light is caused by the bombardment of the retina by very minute corpuscles emitted by the luminous body. Newton himself was never convinced of the truth of his own theory, however, and employed it merely, as he said, because it explained at least provisionally, a number of light phenomena. Owing, however, to the man's enormous influence, his emission theory was well-nigh universally accepted as the definitive explanation of the nature of light (spite of the fact that the undulatory theory had been propounded in 1678) until the time of Thomas Young, who, in 1802, in his book *"On the Theory of Light and Colors"* revived and further developed the undulatory theory and gave an absolute quietus to the theory of Newton.

Christian Huygens was born at the Hague, Holland, April 14, 1629, the second son of Konstantin Huygens, Secretary to the Prince of Orange. Christian Huygens became a very celebrated astronomer, mathematician and mechanician, as well as optician. In 1665 he invented a new and highly successful method of grinding lenses, and, with some of the lenses of his own manufacture, he made a number of astounding discoveries in astronomy—for example, the ring of Saturn. He also invented the pendulum-clock and solved the problem of the "center of oscillation."

In the field of optics his work was, if possible, more important and wide-sweeping still. He it was who established on a firm foundation (even though it did not meet at once with general acceptance) the wave theory of light, which already had been propounded both by Grimaldi and by Hooke. As early as 1678, as above suggested, Huygens announced the results of his investigations on this subject

before the Paris Academy, but not until 1690 did he publish the little "*Traité de la Lumière ou sont Expliquées les Causes de ce qui Arrive dans la Réflexion et dans la Réfraction et Particulièrement dans l'Etrang Réfraction du Cristal d' Islande avec un Discours de la Cause de la Pesanteur.*" Huygens also discovered the polarization of light, a phenomenon described in the same "*Traité.*" Throughout the work, its distinguished author assumes the existence of a luminiferous ether, the fundamental principles of which he was first in history to propound. This theory was afterward further developed and firmly established by Euler, by Fresnel, and, to much the same effect but independently, by Young. (See **Euler, Fresnel,** and **Young,** in this *Encyclopedia.*)

Huygens never married. He died in his native town, the Hague, June 8, 1695.

Another of Newton's great contemporaries was Christoph Scheiner, commonly known as "Father Scheiner." Born in 1575, at Walde, near Mindelheim in Swabia, he entered the order of Jesuits in 1595, became professor of Hebrew and mathematics, first at Freiburg later at Ingolstadt, taught for a number of years at Rome, and finally became Confessor to the Grand Duke at Neisse in Schlesien, where he died July 18, 1650.

Scheiner was a tireless investigator and a keen observer, especially in the field of optics. Among the numerous works in which his valuable observations stand recorded are: "*Oculus seu Fundamentum Opticum, in quo Radius Visualis Eruitur*" (Mühldorf, 1619; Freyburg, 1621; London, 1652); "*Rosa Ursina*" (1626-1630).

Especially memorable in our chosen field is this old Jesuistic father for the following reasons:

1. He was the first in history to submit to experimental test the indices of refraction of the various media of the eye. As a result, he declared the refractive power of the aqueous to be almost the same as that of pure water; the power of the lens to be about the same as that of glass; while the refraction of the vitreous humor stood midway between that of the aqueous and that of the lens.

2. He was the first to measure the curvature of the cornea. This, to employ his own words, is accomplished in this way: "Take a number of glass spheres of various diameters. Set some person opposite to a window, so that the image thereof is mirrored in his cornea. At the temporal angle of the eye hold the spheres, one after another, until a sphere is found which reflects an image of the window of exactly the same size as that reflected from the cornea. The cornea is a section of a sphere of just that curvature. You can easily deter-

mine, in this same way, whether or not the two corneæ are of equal curvature."

3. He showed that the mirrored image of the eye was reflected not, as had been supposed, from the lens, but from the cornea.

4. He showed that the insertion of the optic nerve into the eyeball lies to the nasal side of the posterior pole of the eye.

5. He showed that the pupillary contraction resulting from the action of light is brought about through physiological, instead of through physical, processes. "In an eye freshly removed, no such response takes place."

6. To him has been generally attributed (and, as it seems, with right) the demonstration of the inversion of the retinal image.[4]

7. Most of all, however, he is remembered by the procedure which even today is called "Father Scheiner's experiment." This experiment is made as follows: Pierce a bit of cardboard with a fine needle in two places, whose distance each from the other is less than the pupillary diameter of the eye to be tested. Let the eye look through these two holes simultaneously at a needle. Under certain circumstances the needle will appear double. The circumstances under which the twofold image occurs is not the same for all eyes.

Scheiner could not, or did not, explain his own experiment. This remained to be done by Jacob de la Motte, of Danzig, who pointed out that the needle appeared to be double whenever a pencil of rays from a single point on the needle came to a focus either before or behind the retina, for only under such circumstances could rays from a single point form separate retinal images. This state of affairs occurs in short-sight, uncompensated long-sight, and either imperfect or unemployed accommodation.

The first to measure the minimum visual angle was Robert Hooke, herein already mentioned in connection with the undulatory theory of light. Born on the Isle of Wight in 1635, he studied at Oxford, became assistant to Boyle, was appointed in 1662 "Experimenter" to the Royal Society, in 1678 its secretary, and died at London, of overwork, March 3, 1703.

He was not the first to discover the minimum visual angle, that credit belonging to old Euclid, but he was undoubtedly the first to measure it. The passage in which this great discovery is recorded is found in Birch's "*History of the Royal Society*" (1757, III, p. 120) and runs as follows: "If a graduated ruler is held at such a distance

[4] Elsässer, however, attributes the priority to Kepler. See "D. Funktion des Auges bei Leonardo da Vinci," *Zeitschr. f. Mathematik u. Physik*, 1900, Historisch-Lit. Abt., p. 1.

from the eye that the interval between any given division-mark and the next appears under a smaller angle than one minute, then the sharpest eye can no longer discriminate the two marks from one another." On this great discovery is based a very large proportion of the daily work of every practising ophthalmologist.

A famous 17th century French physicist, immortal for his discovery of the "blind spot," was Edmunde Mariotte. Born in Burgundy in 1620, he became a priest, and was finally prior at Dijon. He was one of the early members of the French Academy of Sciences—which, by the way, was founded in the very year in which the blind spot was discovered. Strange as the fact may sound, the physicist-priest was the very first person in history to investigate the visual function of the optic papilla. To the investigator's great surprise, he found that the ocular end of the optic nerve itself was absolutely devoid of every sort and kind of light perception. Two years after this discovery, Mariotte was called to London for the purpose of demonstrating the blind spot (which, now, was very well known by his name) before the King. The experiment was, of course, successfully repeated by all persons present.

Mariotte died at Paris, May 12, 1684.

So much for the optics of the 17th century, the only portion of the field of ophthalmology which seems to have been exploited in that age with any degree of vigor and success.

Passing now to ophthalmic pathology and treatment, we take up first Richard Bannister, the earliest ophthalmologist in England. The date and the place of his birth and his death are all alike unknown. We do, however, know that he lived in Stamford, England, that he was highly gifted as an operator, and that he wrote the earliest work on ophthalmology to appear in the English language. This book, entitled "*A Treatise of 113 Diseases of the Eye and Eyelids*" (London, 1622), was largely based on Guillemean's "*Des Maladies de l'Oeil,*" at that time very popular.

As the 17th century began with the half-discovery by Fabricius ab Aequapendente of the true location of the lens, so it ended (as regards pathology, at least) with a couple of other discoveries (or one discovery and one doctrine) which completed the work of Fabricius. François Quarré, that is to say, declared, about the middle of the century, that a cataract is really an opacity of the crystalline lens, and not a "corrupt humor" which has collected and inspissated in front of that structure. This latter doctrine had been held and inculcated since at least the Hippocratic period. Quarré, it seems, set up his doctrine on speculative reasoning merely, but he taught that doctrine in a plain,

pellucid and whole-hearted manner, and was, no doubt, the first in history to do so. Some years afterward, a German, Werner Rolfinck, coming to know of Quarré's teaching through a letter from his uncle, Christopher Schelhammer, decided to test the matter by dissections. This he did, discovering that the true position of a cataract is, actually, in, not in front of, the crystalline lens. This was in 1656, a date that should never be forgotten.

So came to an end the ophthalmic 17th century, with mostly a record in optics only (so far as our specialty is concerned) but also with a prophecy of better things to come, especially in cataract.

THE EIGHTEENTH CENTURY.

The 18th century was, first and foremost, the century of cataract. It was also the century of the artificial pupil, of a number of minor

A Peripatetic Dealer in Spectacles and Toys—1740. By Bouchardon.

operations, and also of bifocal spectacles; but, first and foremost, this century belongs to the history of cataract extraction.

We have said that, even in the 17th century, the truth about the actual location of the crystalline lens, as well as of the nature of a cataract, had begun to be disclosed; first, and somewhat feebly, as to the situation of the lens, by Fabricius ab Acquapendente, while, later, the facts were fully discovered (theoretically) by the Frenchman,

Quarré, and (experimentally) by the German, Rolfinck. The truth, however, the simple and absolute truth, as shown by these three men, somehow failed to prosper. It needed a far more vigorous propagation, in the incredulous atmosphere of the day, in order to thrive and blossom and come to fruitage. Now the propagators, or cultivators, of this new and revolutionary doctrine, were a young man and an old one, Michel Brisseau and Antoine Maître-Jan. These two we will treat together.

Brisseau was born (date unknown) at Tourinay, France, practised at Douay, and died in 1743. Maître-Jan, "The Father of Ophthalmology in France," was born in 1650 at Méry-sur-Seine, studied at Paris, practised in his native town, became a corresponding member of the Paris Academy and Body Physician to the King. The date of his death is not known. To the younger man, Brisseau, indeed, belongs the credit of re-discovering the truth about the real location of the lens and the actual seat of cataract, while to him and to the elder man, together, appertains the honor of inducing the world of science in general and of ophthalmology in particular to accept and to act upon that doctrine.

In 1709 was published a volume by Brisseau entitled "*A Treatise on Cataract and Glaucoma*" and in the "Introduction" to this little volume, occurs an historic passage, which explains so simply, clearly and naïvely the respective parts that were played by its author and the much more widely known Maître-Jan, that I here refer the reader to the sketch of **Brisseau,** in this *Encyclopedia,* in which that passage is given in English without abbreviation.

At once a great hubbub and turmoil arose about the new doctrine. Where, in fact, is the crystalline lens situated? What, in fact, is a cataract? These were the questions which agitated the collective, individual, and distracted minds of oculists. And, from out the hubbub, grew a fierce battle, an historic and almost world-wide conflict. We have no space to enter here into the harrowing details of the mighty combat, but will merely mention the names of the generals that were ranged on either side, together with a certain amount of biographic matter concerning each.

Jean Méry was a kind of generalissimo. He was, in addition, one of the predecessors of Helmholtz in the field of ophthalmoscopy.

Born at Vatan (Berry) in 1645, he studied at Paris, in 1681 was appointed surgeon to the Queen, was surgeon in chief to the Hôtel Dieu in 1700, and died in 1722. At the beginning of the battle concerning the new theory about the nature and location of cataract, he fought on the side of the opposition, but, seeing his error early, he

promptly faced about and fled to the other colors—under which he fought most valiantly.

Méry is also a man of importance for other than the reason mentioned. He it was who made (in 1704) the famous "cat experiment." He immersed, that is to say, a cat in water, and, as its pupil dilated (a result of suspended respiration) he beheld in all its glory the fundus of the animal's eye—the entrance of the optic nerve and all the colors and vessels of the choroid.

Méry understood quite well enough that something more than mere pupillary dilatation was necessary to account for the possibility of observing the fundus of the eye when the eye was under water. His explanation, however, of the "something more" was wholly erroneous. He believed, that is to say, that the view of the fundus was rendered possible by the water, because that fluid filled up a multitude of tiny "unevennesses" of the anterior surface of the cornea. Five years later, a Frenchman, de la Hire (1640-1718) stepped forward with the absolutely correct explanation, or, rather, explanations. According to him, the water obviates the refraction of light by the cornea, so that all rays leaving a given point upon the fundus emerge from the eye not as parallel, but as divergent, rays. He also observed, incidentally, that the disturbing light-reflexes proceeding from a cornea *in aëro* are done away with by the water.

Neither of these discoveries (Méry's or de la Hire's) would seem, at the time, to have been considered as of any great importance. Yet, bit by bit, the mosaic of modern ophthalmology was being put together.

Méry is also to be remembered because, as early as 1707, he declared the extraction of cataract to be among the possibilities. "Coming events cast their shadows before," and this was the hundred years of cataract.

In the great fight which raged about the true seat of the lens and the true nature and location of cataract, a prominent leader was Thomas Woolhouse, an English oculist of great skill, but, unfortunately, a charlatan by nature. Born about 1750, he studied at Oxford and Cambridge, then in Centinental Europe, became Court Oculist in England, followed his king to Paris, practised in that city for very many years, was highly esteemed by the laity and damned by all his confrères, and at length returned to England, where he died, very rich, in 1730.

Woolhouse was a bitter opponent of "the new theory," as he called it, and, in this matter, was never a renegade. To the day of his death he firmly believed that the lens was actually separated from the iris

by the so-called "cataract space," and that the disease in question is essentially an accumulation of dry, opaque humors in that space.

Another leader of the opposition to "the new-fangled theories of Brisseau and Maítre-Jan" was Jacob Hovius. Hovius was born at Enkhuisen, Germany, but the date of his birth, as well as the place and the date of his death, is not now ascertainable. He received the degrees of doctor of philosophy, master of arts, and doctor in medicine, all at Utrecht (where he presented a wonderful dissertation, entitled "De Circulari Humorum Ocularium Motu"), but where or with what success he practised, is absolutely unknown. Hovius was one of the minor opponents of "the new theory," and yet it is likely that he did some harm. In the thesis above adverted to, he first announced, or accurately described, two very important matters: (1) the influx and efflux of the ocular humors, as well as a (very inaccurate) means of measuring these fluxions. (2) The "circulus venosus" which is formed by the venæ vorticosæ.

The last of the opposition leaders which here will be considered was Philippe Hecquet. Born at Abbeville, France, in 1661, he studied at Paris and Reims, and returned to his native town. Here he practised but a year or two, and then removed to Paris, where he received his license in 1696 and his doctor's degree in 1697. He died in a Carmelite cloister, April 11, 1737. He was a firm believer in the existence of the cataract space, with all that that implies. His antiquated doctrines appear with sufficient fullness in his work entitled "*Remarks on the Abuse of Purgatives and Bile at the Beginning and the End of Diseases*" (Paris, 1724), but his views were thoroughly demolished by the great du Petit, who is next in order of consideration.

Francois-Pourfour du Petit was the father of Etienne-Pourfour du Petit, and, in addition, one of the most important ophthalmologists of all time. Born at Paris in 1664, he traveled extensively, studied at Montpellier, became a specialist in surgery at the Hôtel Dieu de Paris, went on a military expedition to Flanders, was a Fellow of the Academy of Sciences, and died in 1741.

Among the remarkable performances of du Petit are the following:

1. For soft cataracts that could not properly be couched, Petit reinvented the operation of discission—a procedure still extensively employed.

2. He made a large number of accurate measurements of the ocular tissues and fluids—the first extensive as well as accurate measurements of these parts in all ophthalmologic history.

3. He discovered a number of important anatomical features of the human (as well as the animal) eye, the most important, probably,

being the tiny canal which goes by his name today. This discovery he announced in these words: "I have discovered a small canal, running round the margin of the lens, which I call the plaited circular canal (canal circulaire godronné)." Petit's name was given to the structure by Zinn, the man for whom was named the ligament of Zinn.

4. He greatly improved the couching operation for cataract. His method was first to make an opening in the lower half of the posterior capsule of the lens, and then, slightly withdrawing the needle, to press gently forward upon the lens a very little higher than its center. The lens slid out of its capsule, and took a more forward position on the bottom of the eye than after the older method of operation. Thus, less reaction followed, and more eyes were saved.

5. Petit, as we have said, was one of the great supporters of the new doctrine about cataract, and, in fact, in three concise, well-written letters, he demolished forever the doctrines of Hecquet.

Other important upholders of the doctrine of Brisseau were Valsalva and Morgagni, who were in fact the effective instruments whereby that doctrine was introduced to Italy; also Heister, who took the tidings into Germany, and, greatest of all, Hermann Boerhaave, who, lecturing upon this subject to his most enormous classes, thereby distributed the cataract gospel to every corner of the globe.

Upon these matters we need no longer dwell, because the greatest discovery of the 18th century is pressing for attention—the extraction of cataract.

Every great inventor has a kind of John the Baptist, a predecessor, a forerunner, some one who goes before him to make his paths more straight. So it was with Daviel. His John the Baptist was St. Yves.

Charles St. Yves, the preparer of the way for Daviel, was for a number of other reasons (not related to his predecessorship) one of the most important ophthalmologists of all time. Born at Maubert-Fontaine, near Rocroy, Nov. 10, 1667, he entered the College of St. Côme in Paris, where he studied and practised ophthalmology for more than twenty-five years. In 1711, however, he established his own private Infirmary for eye-patients, where he worked for one more quarter century. He died in 1736.

Among the more impotant innovations, or almost innovations, of St. Yves, are these:

1. Though not precisely the first to employ the nitrate of silver in ophthalmology, St. Yves was nevertheless the first to do so to any great extent, as well as to lay down definite indications for the employment of that substance. In order to render clear the exact position of St. Yves with relation to the history of the drug in question,

I here subjoin a very brief summary of the whole affair until that master's day.

The substance, silver nitrate, was discovered by the Arabian, Geber, in the 8th century. Albertus Magnus, in the 13th century, mentions the drug, apparently invents for it the term, "lapis infernalis," and adverts to the fact that the substance in question produces a blackening of the skin. Angelus Sala, in the early portion of the 17th century, was the first (in his "*Septem Planctarum Terrestrium Spagyrica Recensio*") to recommend the medicinal use of the nitrate of silver. He calls the drug "Crystals of Diana," and "The Mastery of Silver." Then, in some vague way, no one knows exactly how, the drug began to be a little used in ophthalmology. Then came St. Yves, who used it plentifully and often. However, he employed it only in ulcers and abscesses, and never, so far as we know, for suppurative conjunctivitis. "So far as we know" I say with an especial meaning, for, in his great "*New Treatise*" St. Yves declares that, for children born blind, he has a secret wash, which very often cures them. The secret, however, he reserves for himself and his pupils. It is really more than possible, it is in fact extremely probable, that this great Frenchman was the first to employ the silver nitrate in ophthalmia neonatorum. If this surmise be correct, then the man's unethical conduct has simply removed the most brilliant star from his glittering crown.

2. St. Yves was the first to give an exact description of gonorrheal ophthalmia. Astruc, "*De Morb. Vener.*" (Paris, 1740) describes the disease in a vague and unsatisfactory manner, and so does Bertrandi, in his "*Chirurgie*" (1763). Moreover, ophthalmia neonatorum was fairly well described by Severus (who flourished 3d century A. D.) as reported by Aëtius, in a passage which the reader will, beyond question, recall. But St. Yves was the first to describe, with any degree of precision, a case of ocular gonorrhea in the adult.

3. St. Yves was also the first to report a case of gonorrheal ophthalmia produced by conveyance of the contagious secretion from the sexual organ to the eye. The patient was a young man who had long made a practice of washing his eyes every morning with his urine. The practice was continued after he had become a victim of gonorrhea, and so he acquired also gonorrheal ophthalmia.

4. St. Yves was also the first to describe a case of herpes zoster ophthalmicus. However, he did not think of the trouble as an affection of the first and second branches of the trigeminus nerve, but only as a variety of erysipelas. The true conception of the nature of the disease in question was first arrived at by Bärensprung in 1861.

5. St. Yves was also the first to describe the changes produced in the eye by variola.

6. St. Yves was the first to make injections into the anterior chamber. These he carried out by means of a tiny syringe, and for the purpose of removing unabsorbable pus from the chamber in cases of corneal ulceration occasioned by smallpox. The cleansing liquid was simply warm water.

7. The most important fact, however, about St. Yves is this: He was first of all in history to extract a cataract *en masse*. Of this there can be no doubt. The removal of cataract by suction was, as we have seen, invented by an Arab, Ammar, in the tenth or eleventh century. Such a removal of the lens, however, was not, of course, *en masse*. Therefore the greater credit to St. Yves. We must, however, in justice to the immortal Daviel, declare that the lens which the earlier man removed—i. e., in 1722—had already been dislodged from its normal position in the *fossa patelaris*, thrown through the pupil, and received in the anterior chamber. To Daviel belongs the highest honor in operative ophthalmology, that, in a word, of having extracted a cataract *en masse* from its normal position behind the pupil and the iris.

The "fullness of the times" had come, and, with it, Daviel.

Jacques Daviel was born, the son of a village notary, at Barre, near Rouen, France, Aug. 11, 1696. All that we know of his education is that he studied surgery both at Rouen and at Paris. For a time he was assistant surgeon in the army. Of his long, persistent, and heroic service in fighting the plague at Marseilles, I have told with considerable detail in his biographic sketch in this *Encyclopedia*.

In 1728 he began to devote himself exclusively to diseases of the eye, and soon had a great reputation both at home and elsewhere. He was, in fact, not infrequently summoned to operate on the super-precious eyes of royalty in several lands.

The story of Daviel's invention of the extraction operation is, in brief, as follows:[5] On April 8, 1745, in the course of a cataract depression on Brother Felix, Hermit of Aiguille, in Provence, a certain accident occurred, namely, "several fragments of the broken up cataract arrived in the anterior chamber," and then the chamber filled with blood until the surgeon could no longer see the needle with which he was endeavoring to perform the depression. "This accident decided me," said Daviel, "after the example of M. Petit, to open the

[5] For full English translations of the most important of Daviel's communications upon the subject, the reader is referred to my sketch of **Daviel** in this *Encyclopedia*.

transparent cornea for the purpose of removing the blood and the fragments of the lens from the anterior chamber.'' So he opened the cornea with scissors, and then ''came out all that had been in the anterior chamber, the pupil became clear, the patient distinguished at once all objects held before him.''

This operation, as the reader at once perceives, is little if anything more than merely a repetition of the procedure of St. Yves, i. e., the removal of a cataract *via* the cornea, not, from its normal position behind the pupil and the iris, but out of the anterior chamber, a space into which it had been dislocated before the cornea was opened. Truly, in one respect the procedure is not so important even as that of St. Yves, for the latter removed the lens *en masse*, while Daviel removed nothing but broken up fragments.

And yet this proceeding of Daviel has now and then been called ''the first extraction of cataract''!

However, this bit of experience was, to Daviel, an extremely important matter. ''This case,'' he says, ''which accident had brought before me, occasioned me to decide that, thereafter, I would only operate in that very way in which I had carried out the procedure for the Hermit, through an opening of the cornea to go in quest of the lens in its capsule, to bring it through the pupil into the anterior chamber and to extract it from the eye.''

''I did this operation,'' he next remarks, ''for the first time for a woman.'' The name of the woman, however, and the date and place of the operation he does not give. Moreover, it appears that, even in this operation, he did not extract the lens *en masse*. Thus, he continues: ''I opened the cornea in the way mentioned, brought the little spatula, which I have already described, upon the upper portion of the cataract, made it free and drew it piecemeal from the eye by the aid of this instrument.''

The whole proceeding had moved a little forward, it will be observed, as compared with the extraction (so-called) in the case of the Hermit of Aiguille, for, though the lens was not extracted *en masse*, it was acted on by instruments which, from the very beginning of the operation, were introduced *via* the cornea.

Finally, there came an operation in which the procedure was truly a complete extraction—i. e., complete in the modern and present-day sense.

The case was that of the right eye of a certain M. Garion, master wigmaker—who, therefore, occupies a considerable place in history. Now, even in this case, Monsieur Daviel at first attempted a depression, but failed, as it seems, to budge the lens in the slightest. ''Then,''

says he, "I decided to open the lower portion of the cornea, in order to get my needle the more certainly into the posterior chamber. Then, for a long time, I held the cornea up by a small forceps, and brought forth the lens."

The first cataract had been extracted!

Ophthalmology could never be the same again.

In no irreverent or sacrilegious spirit it might indeed be said that Daviel had spoken these words: "Let there be light," and that then there was light.

It sometimes seems, as we gaze across the ophthalmic centuries, as though the whole of ophthalmology had been but working upward toward this miracle, this crowning act and glory of our crowning art and science. And we tremble and shudder as we try to imagine what the final issue might have been in ophthalmology, as in other matters, had the world-affecting outcome of the Saracenic crisis been other than it was. Not only might America have remained eternally a hidden continent, not only might "the art preservative of all arts" have staid interminably in time's womb, together with the soul-expanding discoveries of Copernicus, but, also, and equally important, however at first it may seem, that orb of apparently insignificant opaque matter which old, wise Constantinus Africanus mistakenly called a "cataract," and which, of a simple verity, has hidden from countless multitudes of human beings the forms and colors of the entire universe—THAT globe also might never have been "discovered."

What things were trembling in the balance!

How little it took to tip the scale in the proper direction!

Thanks indeed to those Nestorian Christians who caused the black, fierce Arabs to change their not too easily changeable minds.

Daviel's cataract extraction, the first in the modern sense of the term, was performed on the 8th of April, 1747. It was not, however, reported to the world till 1748, being published then in "*Mercure de France*" at pages 198-221. Inasmuch as the date of an innovation is, by the general consent of scientists, understood to be the time of its making public, the latter of these years, i. e., 1748, is generally taken as the date of the first extraction of cataract. All ophthalmologists, however, should remember in addition the actual day and year when the operation was truly first performed.

It remains to be recorded that the operation was "successful" from the patient's, as well as from the doctor's, "angle of consideration." There were, in fact, no bad results, and "the patient distinguished objects very well."

"After this time," says Daviel, "and during the three following

years I performed this operation several times upon the living, in order to get accustomed to it gradually. But, for the first time, while on a journey to Mannheim for the purpose of treating the Electoress of Zweibrücken for an old affection of her left eye, I came to a firm decision, in the future to operate for cataract only by extraction of the lens.

"I had occasion to pass through Liège and to stay there for a time. There I performed six operations in accordance with this method, and all with the greatest success. One which I performed at Cologne on a priest of a religious order, yielded a very surprising result, inasmuch as the cataract was as soft as jelly. In spite of that fact, the priest was able, fourteen days later, to read the mass."

Daviel at once became famous. Doctor and layman alike were pleased to sound loud paeans to the conqueror of grim darkness. The painter, François de Voge, whom Daviel had cured of an adherent cataract, designed (using, it is well to remember—for his other eye was absolutely blind—the very sight that Daviel had given him) a beautiful allegorical picture "representing the famous surgeon marching to immortality." This picture, together with an explanation of its symbolism, will be found in the biographical sketch of **Daviel,** Vol. V of this *Encyclopedia*, together with a eulogistic poem by "Mr. L. Chr. D. F.," which appeared in the "*Mercure de France,*" in July, 1752.

There remains to be described the technique of extraction as performed by Daviel. "On the day selected for operation," he laid in order the following appurtenances: "bandages, compresses, tiny bits of linen, lead plaster cut egg-shaped, pledgets of cotton, warm water and wine." The instruments were these:

"1. A needle, sharpened to a point in front, cutting on the side, somewhat curved, and lance-shaped, for the first opening. 2. A needle blunted off in front, cutting on the side, also curved, for the purpose of enlarging the first opening. 3. Two curved, convex scissors. 4. A small spatula, of gold, silver, or steel, slightly curved, for the purpose of lifting the cornea. 5. Another small needle, sharp forward and cutting on both sides, for the purpose of opening the anterior capsule of the lens. 6. A small spoon of gold, silver, or steel, to facilitate now and then the exit of the lens or to extract pieces of its substance when these remain behind in the pupil. 7. A small pincette, for the purpose of removing bits of membrane, which may perchance be present."

The patient was placed on a stool, or chair without a back, and the operator sat on a considerably higher chair before him, supporting

his elbows on his own knees. The fellow eye was covered with a bandage. An assistant, standing behind the patient, placed one hand beneath the patient's chin, while, with two fingers of his other hand, he elevated the upper eyelid.

The surgeon himself drew down the lower lid. Then, having opened the cornea, close to the sclera, with the sharp-pointed needle, he enlarged the opening a little with the blunt-pointed needle, to right and to left.

By now the cornea had, of course, become flaccid, so the further enlargement of the wound was made with the scissors—again both to right and to left.

The wound having been made large enough, the cornea was tightened forward by means of the spatula passed well up behind it, and then, with the edged and pointed needle the capsule of the lens was opened. Next, the spatula was passed all round between the lens and the iris, in order to break up any possible adhesions which might exist between these structures.

Then the eyeball was pressed upon, very, very gently; the pupil dilated: the lens ran out and glided down on the cheek.

The pupil having been set in order, the eye was dressed in this way: The eye itself was wiped with a delicate sponge, wrung out of lukewarm water, containing a very few drops of alcohol; the lids were closed; plaster was laid over them; and the whole was secured with a bandage, but without the slightest pressure.

The patient was kept in a dark room, and the eye was bathed twice or thrice daily in a softening and solvent solution. Blood-letting, a correct mode of life, and the usual surgical principles, were not forgotten.

Despite the great advantages of Daviel's invention, the operation of cataract extraction, after a brief preliminary period of almost universal acclaim, passed partly out of favor; and then there began a most bitter contest for supremacy between the old procedure and the new. There is little that is memorable about this three-times-thirty years war, which raged from approximately 1755 till nearly the middle of the 19th century. Suffice it to say that the armies of couchment, or depression, were led by Pott, in England, Dupuytren, in France, Scarpa, in Italy, and Langenbeck, Buchhorn and a number of others in Germany. The leaders of the opposite host were Sharp, Wenzel, Wathen, Warner, Tenon, Pamard, Richter, Beer and Thomas Young. This war was made perhaps a little longer than it would otherwise have been, by the invention, in 1785, by von Willburg, of the modified depression procedure, termed "reclination." This consisted of a dis-

location of the lens not merely downward, but downward and backward, so that the anterior surface now looked upwards, its posterior surface, however, downward, being, in fact, in contact with the floor of the vitreous chamber. A further development in the method of couching consisted in the invention, in 1806, of keratonyxis, by Wilhelm Heinrich Julius Buchhorn, who was only a student and who described his new proceeding in his graduation thesis, *De Keratonyxide* (Halle, 1806).

For the sake of continuity, which is here important, I encroach a little upon the history of the 19th century, and add the following abstract of the most important improvements in, or at least alterations of, the extraction operation, which have been introduced to date since the time of Daviel.[6]

De la Faye, in 1752, was the first to suggest that the lance and scissors of Daviel be laid aside, and the cut be made with only a single knife.

Sharp, however, of London (April 7, 1753) was the first to carry out De la Faye's idea.

De la Faye himself performed the operation with only a single knife, June 11, 1753.

The single knife "had come to stay." Numerous modifications, however, were made in the course of the next six years. Of these the most important were those of Poyet, of Paris (1753); Joseph Warner, of London, (1754); Louis Béranger, of Bordeaux (1756); Jacques René Tenon, of Paris (1757); Pamard, of Avignon (1759). Numerous other knives are described in the non-historic portions of this work.

A very important addition to the technique of cataract extraction was furnished by Himly, who, in 1801, reported the employment of artificial dilatation of the pupil in connection with this procedure. Himly was not the first to bring about an artificial dilatation of the pupil. He was simply the first to produce mydriasis as a preliminary to the extraction of cataract.

The "preliminary iridectomy" was introduced by von Mooren, of Düsseldorf, in 1864. The inventor of iridectomy (but only as a means of forming an artificial pupil, not as a matter connected with the cataract operation) was Beer (in 1798).[7]

[6] Cataract spectacles, as the reader will readily recall, were first invented, or at least described, by the Spanish notary, Daça de Valdes, far back in the 17th century (1623). Bifocal spectacles, or "Franklin's glasses," as for more than a century they were called, were invented by Benjamin Franklin in 1784, but, though belonging to the 18th century, they form the beginning of American ophthalmology, and, for that reason, their discussion will be reserved for the fifth division of our subject, "Ophthalmology in America."

[7] Iridectomy as a means of treatment for glaucoma was first employed by von Graefe. Of this hereafter.

One of the most important modifications of the cataract incision was the so-called "linear incision" of Albrecht von Graefe, first performed in 1866. "It placed the wound in the sclera as near to the iris as possible, and involved iridectomy." The immediate object was to secure an incision which should constitute a segment of that greater circle of the globe of the eye in which the points of puncture and counter-puncture lay. The remoter purpose was to obviate gaping of the wound and suppuration. For the execution of this procedure its distinguished inventor devised also a straight and narrow blade of 2-3 mm. in width, which is still well-nigh universally employed in cataract extraction and still is called "von Graefe's knife." The operation itself, however, was soon modified, and, in fact, to all intents and purposes was soon rejected. For one objection, difficulty was experienced in getting the wound of a sufficient size to permit of the passage of a very large lens. Again, irido-cyclitis, either early or late, and sympathetic ophthalmia destroyed too many eyes that had been subjected to extraction by the linear method.

The intracapsular operation was undoubtedly invented by De la Faye in 1753, developed very assiduously both by Sharp and by Beer, and, very recently, by Smith, of India. Its value is still in question.

On the whole, it is truly remarkable how extremely little of actual, unquestionable merit (aside, of course, from general matters like anesthesia and asepsis) has really been contributed to the senile cataract extraction operation since the days of the great man, Daviel.

Thus far, the 18th century has proved to be almost exclusively occupied with matters concerning the crystalline lens, particularly with cataract. We must not, however, forget the work of Cheselden, inventor of the artificial pupil.

Cheselden was born at Burrow, England, in 1688, and when 15 years of age began the study of medicine with the celebrated anatomist, Cowper. At the age of 23 he was teaching anatomy. He soon became surgeon to St. Thomas's Hospital, body physician to the Queen, and fellow of the Academy of Surgery at Paris. He was world-renowned as an operator, especially for urinary calculus. He died at Bath, England, 1752.

For the performance of his artificial-pupil operation, Cheselden employed "a sort of needle with an edge on one side, which, being passed through the tunica sclerotis, is then brought forwards through the iris. . . . This done," he continues, "I turn the edge of the needle and cut through the iris as I draw it out: . . ." These passages of his are taken from the first report of his operation, entitled "An Explication of the Instruments Used in a New Operation on the Eyes" (*Philos.*

Transacts., Vol. XXXV, for 1727 and 1728, London, 1729). The second account of his procedure appeared in the Appendix to the fourth edition of his "*Anatomy*" (1730), and runs as follows: "Three figures of eyes to explain an operation, which I invented some years ago, and printed a short account of in the *Philosophical Transactions,* and have often practiced with success. The distemper for which the operation is performed, is either a total closure of the pupil, which is sometimes natural, and sometimes happens from inflammations; or else where the pupil is extremely contracted, and the inner edges of the iris growing to a cataract, or part of a cataract after couching.[8] The manner of doing this operation is thus: the eyelid being firmly held open by an instrument, a small knife or needle, edged on one side, is thrust through the Tunica Sclerotis, as in the lower figure; and then forwards through the Iris, the edge being turned to the Iris; in drawing of it out, a slit is cut as in the two upper figures. When this distemper is without a cataract, it is best to make the operation in the middle, as in the upper one; but if there is a cataract, or part of a cataract, then to make it higher that the cataract may not obstruct the light. These cataracts are generally very small, and sometimes by reason of their adhesion not to be removed."

Now what Cheselden really made, as the reader has already noticed, was not an iridectomy, but an iridotomy. He did not remove the smallest portion of the iris, but merely incised that structure. Iridectomy, as stated, we owe to Joseph Beer, of Vienna, who invented that procedure in 1798, but did not describe it till 1805. Iridectomy, by consequence, belongs to the 19th century.[9]

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[8] As will be recalled, there was no extraction of cataract in those days, Daviel's first extraction having been performed in 1747.

[9] Some of the minor contributions which were made to ophthalmology in the 18th century were as follows: By Pierre Demours, numerous anatomical discoveries relating especially to the cornea, choroid, vitreous and aqueous humors (including perhaps the so-called "membrane of Demours" in 1740). By Albrecht Haller, in 1763, the first proposal to extract the lens in high-degree myopia—a proposal which was later made again by Desmonceaux (i. e., to Baron Wenzel, who, somewhat prior to 1775, began performing the operation. The procedure at once fell into disuse, to be revived by Weber and Mooren in 1758, and again by Fukala in 1889.) By Felice Fontana, the first description of the spaces which bear his name, in 1777.

The following facts may also be recorded as of a certain collateral interest to ophthalmologists: La grippe, or influenza, first became pandemic in 1709, whooping cough a little later, and diphtheria in the latter portion of the century, while typhoid fever was first described in 1762, by Roederer and Wagler, under the name of "Schleimfieber." John Hunter (1728-1793) was first to describe the Hunterian chancre and phlebitis.

The Nineteenth Century.

And so we have come to the crowning century of all—the 19th. We hardly need to remind ourselves of the great advances in other fields than that of medicine—the railway, the telegraph, the telephone, the electric light; the bicycle and the automobile; the cotton gin and the reaper; the iron-clad ship and the submarine; with scores on scores of other miracles which occur at once to any mind. All these marvelous inventions (to express the matter briefly) made of human life itself a strangely different thing from what it had ever been before. The railway alone, perhaps, produced as great an alteration in the very appearance of the earth (not to mention the more important matter of human relations) as all the inventions and discoveries of the mediæval period put together.

The advance in general medicine and surgery and in other specialties than ours, was no less marked. The germ-theory of disease (now no longer a theory, but a demonstrated fact) dates from the discovery, in 1836, of the yeast plant by Latour.[10] Later, Pouchet declared that putrefaction and fermentation have their origin in germs which are normally present in the atmosphere. These germs were actually shown to the human eye by Louis Pasteur, who also demonstrated beyond peradventure the declaration of Pouchet. To Billroth would seem to belong the honor of demonstrating the *specific character* of pathogenic microorganisms. Then came a host of observers, too numerous even for listing in this place. We may, however, add that the itch-mite was discovered by Renucci in 1834; the fungus of favus, by Schoenlein, in 1839; the bacillus anthracis, by Davaine, in 1850; the gonococcus, by Neisser, in 1879; the staphylococcus, by Ogston, in 1881; the bacillus tuberculosis, by Koch, in 1882; the micrococcus of pneumonia, by Friedländer, in 1883; the Klebs-Löffler bacillus, in the same year; the tetanus bacillus, by Nicolaier, in 1884; the streptococcus, by Rosenbach, in the same year; the spirochæta pallida, by Schaudinn, in 1905, that, finally, the theory of phagocytosis was promulgated by Metchnikoff in 1884; while the Wassermann test was published in 1907, and the modification thereof by Noguchi, two years later.

The antiseptic treatment of wounds was introduced by Joseph Lister in 1868.[11]

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[10] Yeast cells had been observed by Leeuwenhoeck, who, however, did not understand that these structures were living organisms.

[11] And brought to the New World, a very little later, by H. O. Marcy, of Boston. See "*The Medical Pickwick,*" June, 1915, pp. 235-237, and "*The Canadian Journal of Medicine and Surgery,*" May, 1912.

Anesthesia,[12] although discovered in America, may well enough be mentioned here. The salient points would seem to be as follows: The fact that ether was capable of producing a general anesthesia had long been known to the world of science, but the first to employ this anesthesia for a surgical purpose was Wm. T. G. Morton, of Charleston, Mass., a dentist. The date was Oct. 16, 1846; the place, the clinic room of the Massachusetts General Hospital; the operation, the removal of a tumor from the neck; the immortal operator, Dr. John Collins Warren, of Boston—all facts which should be remembered by every physician, whether general or special. The merits of the various rival claimants—Long, Wells, Jackson—we cannot here consider. The whole underlying story of the discovery of surgical anesthesia is, in fact, a pitiful, long-drawn tragedy—an obligato, rather, of discords, sorrow, and even untimely death, blending in strangest fashion (after the manner of human life in general) with the great, triumphant hymn of humanity over its wonderful release from surgical suffering. Those who would find the matter expounded at not too great a length, may turn, for example, to Park's "*An Epitome of the History of Medicine,*" pages 300-315.

The first laparotomy (this also in America) was performed by Ephraim McDowell, a country practitioner of Danville, Ky., in 1809. The results of this earliest ovariotomy are known to all—the appendicitis operation, the surgery of the gall tract, etc.

In the 19th century, also, was born the specialty called gynecology, its "father" and "mother" combined being J. Marion Sims.

In 1895 came the Roentgen ray, within the memory of the most of those who read these volumes, and so we shall have to conclude this all-too-bald a summary of the course of general medicine in the 19th hundred-years.[13]

The 19th century in ophthalmology was no less wonderful, for, to

[12] Before the employment of ether as a surgical anesthetic, the following substances had principally been used: In the earliest ages, opium and alcohol. Mandragora was also lauded, very much later, but seems to have been without effect. Among the Indians and other Orientals, bhang, or hasheesh. Mesmerism, which began to be employed at Paris by Mesmer (whence the name) in 1776.

[13] The other portion of the fugue of which we have spoken before, was also, of course, to be heard in the 19th century—the anti-Hippocratic theme. Passing over a thousand popular fads and fallacies, we need to mention merely the great, scientific rejuvenator discovered by Brown-Séquard—testicular fluid. It had a considerable vogue for a number of years, and then itself began to suffer from premature decay—and finally alas it died. The one part of a fugue, however, is apt to beget, or to evoke, the contrasting theme, and so it was in this case. Brown-Séquard's testicular fountain of Ponce de Leon, produced no marvelous rejuvenation of anybody, and yet it really served to direct the attention of physicians to possible values in animal extracts, and so we have today the really helpful thyroid extract, and so on.

that marvelous epoch belong ophthalmic hospitals; professorships; societies; journals; treatises, or text-books; also test-types and refraction; asepsis; anesthesia; iridectomy for glaucoma; and, lastly, that miracle of all ophthalmic miracles, the ophthalmoscope.

We shall first consider the more important accessories of the art—professorships, hospitals, societies, journals and treatises—and, later, will take up the substance of the art itself—ophthalmic anatomy, physiology and diagnosis, pathology, prophylaxis, therapy and surgery.

Professorships.

France.—In 1765 Lamartinière founded at the College of St. Côme, Paris, a chair of ophthalmiatry. This was the first of its kind in history,[14] and the first incumbent was Dehais-Gendron. His immediate successor was Louis Becquet, and the next to follow was Jacques Arrachart. A similar chair was founded at Montpellier, just a little later than the chair at Paris, but, on Aug. 19, 1792, all the universities were abolished by the Convention, and with them, of course, the medical schools and the chairs of eye diseases.

On Dec. 4, 1794, three of the medical schools were re-organized—Paris, Strassburg, and Montpellier—but not one single chair of ophthalmology was instituted.[15] France, in fact, although the first to establish chairs for instruction in diseases of the eyes, remained from Aug. 19, 1792, until about the middle of the third decade of the 19th century, wholly devoid of chairs of the kind in question. Then came the turn, at last. Rognetta, an Italian, delivered a course of lectures on ophthalmology at the Paris Ecole de Médecine. Carron du Villard delivered a public course of lectures in ophthalmology at Paris in 1834, soon removing, however, to Mexico, while, about the same time, a German immigré, Julius Sichel, began to deliver at the Hôpital St. Antoine, an excellent course of lectures which became a permanent institution. Sichel was followed in 1838 by Sanson.

Austria and Germany.—In 1773, just eight years after the founding of the chair at St. Côme, the earliest professorate of ophthalmology was erected at Vienna, with the well known Joseph Barth (appointed by the Empress) as "Professor der Augenheilkunde."

Barth was a bad instructor, but at least he had the honor of training the much more famous men, Joseph Beer and Adam Schmidt. The

[14] Lectures on the eye had, of course, been given incidentally in connection with surgical courses, very long before this time, e. g., by Boerhaave as early as 1708.

[15] Seneaux, in the re-organization of the school at Montpellier, was made "professeur d'accouchements, maladies des femmes et éducation physique des enfants."

circumstances are as follows: In 1789 the Emperor, Joseph II, commissioned, or rather commanded, Barth to educate two young physicians in ophthalmology, there being at the time, in addition to Barth, no expert on this subject throughout the whole of his domains. Barth was given the privilege of selecting the physicians, either from within, or from without, the Austrian empire. He was also granted a yearly allowance of a thousand guldens for the maintenance and education of these ophthalmic students.

Barth chose his prosector—Ehrenritter—and Johann Adam Schmidt, who, at the time, was instructor in anatomy and surgery at the Joseph's Academy, and these young men he trained for about two years, retiring then to private life. A few months later, Ehrenritter died. Schmidt, however, in 1795, was appointed full professor of ophthalmology at the Josephinum. Meanwhile, Georg Joseph Beer, who had studied ophthalmology privately with Barth, beginning in 1786, and who had also, in the very same year, established a private infirmary for diseases of the eye in Vienna, had become a celebrated ophthalmologist, and for him a special chair in ophthalmology was created at the University of Vienna in 1812.

Schmidt and Beer were brilliant teachers, as well as skillful operators. Schmidt, however, devoted himself, as the years went by, more and more to general surgery,[16] while Beer, on the contrary, became, each day, a better ophthalmologist, and, especially, a better teacher of ophthalmology. The consequence was that, forth from his lecture rooms proceeded, in the seven brief years of his professorate, the remarkable men who afterwards founded modern ophthalmology, especially the systematic teaching of that branch, throughout Switzerland, Austria and Germany.[17] Among his pupils were the following: Konrad Johann Martin von Langenbeck (1776-1851) at Göttingen, teacher of ophthalmology and founder, in 1807, of the Clinical Institute for Surgery and Ophthalmology. Phillip Franz von Walther (1782-1849) professor of surgery and ophthalmology first at Bonn, then at Munich, teacher of students from every portion of the civilized world, co-founder in 1820, with C. von Graefe, of the *"Journal für Chirurgie und Augenheilkunde;"* Friedrich Phillip Ritterich (1782-1866), professor of ophthalmology at Leipsic, and one of the founders of the Leipsic Eye-Infirmary. Friedrich Jaeger (1784-1871) son-in-law of Beer, professor, with high distinction, of ophthalmology at

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[16] He performed, however, as we shall see hereafter, the inestimable service of founding, together with Himly, the first of all ophthalmic journals—i. e., in 1804.

[17] Although the first professor of ophthalmology in Germany, Carl Himly was not a pupil of Beer.

the Viennese Joseph's Academy for almost twenty-three years, chief physician to the Austrian army, a wonderful teacher and operator. (Through his son, Eduard Jaeger—1818-1884—inventor of the Jaeger test-types, first to employ the ophthalmoscope as a means of determining refraction, and first to discover the ophthalmoscopic appearances due to diabetes, the influence of Beer was carried still further.) Traugott Wilhelm Gustav Benedict (1785-1862) professor of ophthalmology in the Leopold University at Breslau for nearly fifty years, and discoverer of the etiologic relation existing between some cataracts and diabetes. Johann Nepomuk Fischer (1787-1847) founder of ophthalmology in Bohemia, professor of ophthalmology for years at the University of Prague, and the first physician appointed to the Prague ophthalmic institute. Carl Ferdinand von Graefe (1787-1847) a peerless operator on the eye, a most brilliant lecturer, and long professor-in-ordinary of ophthalmology at the University of Berlin, as well as Director of the Clinico-Chirurgico-Ophthalmic Institute.[18] Beer's influence on the ophthalmology of the present moment, *via* Alfred Graefe (Carl Ferdinand's nephew) and *via* Albrecht von Graefe (Carl Ferdinand's son) is hardly to be over-computed. Johann Gottlieb Fabini (1790-1847) professor of ophthalmology at Pesth for almost 31 years, as well as Director of the Institution for the Indigent Blind and Superintendent of the Infirmary for Eye Patients. Antoine de Rosas (1791-1855) marvelous teacher in two languages, professor of ophthalmology at first in Padua, later, and for many years, at Vienna. Karl Heinrich Weller (1794-1854) renowned instructor at Halle, later at Dresden. Karl Joseph Beck (1794-1838) brilliant teacher of brilliant pupils at Freiburg, Switzerland. Maximillian Joseph Chelius (1794-1876) founder of the Chirurgico-Ophthalmic Hospital at Heidelberg, and teacher of ophthalmology in that city for more than 47 years. Joseph Pieringer (1800-1879) professor of ophthalmology at Gratz for 32 years, student of ophthalmia neonatorum and distinguished predecessor of Credé. A wonderful record indeed for the seven brief years of instruction by Joseph Beer.

Another most marvelous teacher and begetter of teachers of ophthalmology was a German, Karl Himly, who, however, was not a disciple of Beer. In 1803 he began to deliver at Göttingen a course of lectures restricted to ophthalmology exclusively, being the first in Germany to do so. Seven years later, Carl von Graefe (a pupil, as we have said, of Beer) began to lecture at Berlin, and, five years later still, Benedict (another of Beer's disciples) became professor of oph-

[18] We may mention incidentally that Carl Ferdinand von Graefe was the first German to tie the innominate artery and to perform a staphylorrhaphy.

thalmic surgery at the University of Breslau. Then three more of Beer's great students began to teach in Germany: Fabini, at Pesth, in 1817; Chelius, at Heidelberg, in 1819; and Beck, at Freiburg, in 1821. And so the work had got well started in Germany.

Italy.—The first ophthalmic instruction in Italy was given by Giovanni Battista Quadri, in 1815. (Quadri was also the founder, as we shall see hereafter, of a great ophthalmic hospital.) In 1817 courses began to be held in Pavia by Francesco Flarer (the inventor of Flarer's operation for trichiasis).

England.—The earliest teacher of ophthalmology in the United Kingdom was George James Guthrie (1785-1856) who, in 1817, delivered his first course of lectures on diseases of the eye at the Royal Westminster Eye Hospital, London, an institution which he himself had founded the year before. Two years later, William Mackenzie began to lecture at Glasgow, and in 1824 William Lawrence delivered at the London Ophthalmic Hospital a course in ophthalmology, which has fortunately been preserved in the London "*Lancet.*" In the last named year, moreover, John Morgan also began to lecture in ophthalmology at Guy's Hospital, London, and in 1829 Richard Middlemore at the Birmingham and Midland Eye Hospital. And from that time forward the name of the lecturers was legion.

Belgium and Spain.—The father of ophthalmology in Belgium and the earliest teacher of the subject in that country was Florent Cunier, who established in 1840, at Brussels, an ophthalmic clinic in which he gave instruction until his untimely death, twelve years later, at the age of 40. The earliest teacher of ophthalmology in Spain, so far as I have been able to learn, was Delgado Jugo (1834-1876) founder of the Madrid Ophthalmic Institute.[19]

Hospitals and Infirmaries.

Germany and Austria.—The first private ophthalmic hospital [20] was that of Joseph Beer at Vienna. This was opened in 1786, and was free to the poor. It consisted merely of a couple of rooms in Beer's own dwelling. Twenty years later it was expanded into a public institution by the order of Kaiser Joseph, and in 1818, consisted of three

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[19] American professorships, hospitals, infirmaries, societies, periodicals, and text-books are all reserved for Division V, which, as stated, will be devoted wholly to America.

[20] Hospitals of a general character are extremely ancient. Thus, the temples of Æsculapius at Athens and Epidauros were a kind of hospitals. Hospitals of a charitable nature are an outgrowth from Christianity.

large halls, one of which was used as lecture room, while the others, as wards, contained, altogether, some eighteen beds.

England.—The first public exclusively ophthalmic and aural hospital in the world was that which is known today as Moorfields, or The Royal London Ophthalmic Hospital. It was founded in Charterhouse Square, London, by John Cunningham Saunders, in 1805, being then, however, an ophthalmic *and aural* hospital. Its name at first was "The London Infirmary for Curing Diseases of the Eye and

The Royal London Ophthalmic Hospital.

Ear." In 1807 the work of this institution was restricted to eye diseases. In 1821 new quarters began to be built in Bloomfield Street, Moorfields, and, in 1836, the present appellation, "Royal Ophthalmic Hospital," was bestowed upon it. In 1899 the institution was removed a second time--i. e. to City Road, where it stands today. For a more detailed consideration of this hospital, see **Saunders, John Cunningham.**

At the present time, in England, the following are the more important hospitals devoted either to diseases of the eye alone, or else to diseases of the eye, ear, nose and throat:

The West of England Eye Infirmary. (The second in England. Founded at Exeter in 1808 by John Cunningham Saunders and William Adams.)

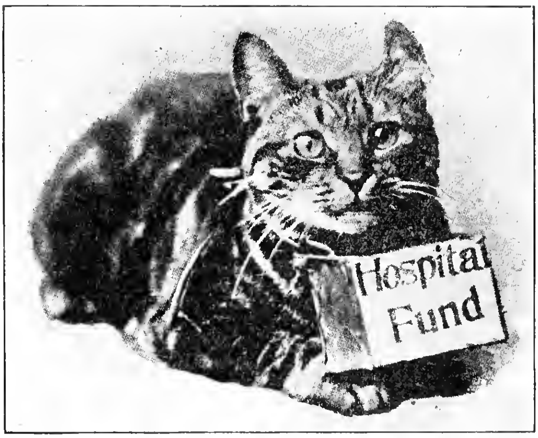
The Bristol Eye Hospital. (The third in the United Kingdom. Founded by a number of collaborators in 1810.)

The Royal Manchester Eye Hospital. (Founded in 1814.)

The Birmingham and Midland Eye Hospital. (Founded in 1823 by a number of collaborators.)

The Glasgow Eye Infirmary. (Founded by Wm. Mackenzie and G. C. Monteath in 1824.)

The Central London Ophthalmic Hospital. (Founded in 1843 by H. Haynes Walton and A. S. Smee in Gray's Inn Road, W. C., London.)



"Tiger," a Cat Which Collected Funds at Broad Street Station, London, for the Moorfields Eye Hospital.

The Western Ophthalmic Hospital. (Founded in 1856 by a number of collaborators in Marleybone Road, W., London.)

The South London Ophthalmic Hospital. (Founded as The Royal Eye Hospital, London, by J. Zachariah Lawrence in 1857.)

There are today in the United Kingdom, exclusive of the colonies, something over forty ophthalmic hospitals, infirmaries, and similar institutions.

France.—The first ophthalmic hospital in France was founded by Victor Stoeber in Strassburg (a city which then belonged to France) in 1845. At its beginning the institution had only ten beds, but it rapidly grew both in size and in usefulness.[21]

[21] Owing to war conditions, it has been absolutely impossible to secure the requisite information about ophthalmic hospitals in France and one or two other countries.

Societies.

The first ophthalmological society was, strangely enough, not a national, or a local, but an international, affair. The first *international ophthalmologic congress* (which was also the first international medical meeting of any sort or kind) met at Brussels in 1857,[22] from Sep. 13 to 16. Its founders were Bosch, Fallot, Hairion, van Roesbrook and Warlomont. The meeting was eminently successful, but no provisions were instituted for any further congresses.

In September and October, 1860, the so-called "Société Ophthalmologique Universelle" was convoked at Paris by Leport and Vauquelin, but only fourteen ophthalmologists attended. The second convocation was held, at Paris also, in 1862, and was more successful, 113 members being present, and the total membership amounting to nearly three hundred.

A Recent View in the Out-Patient Department of Moorfields Eye Hospital, London.

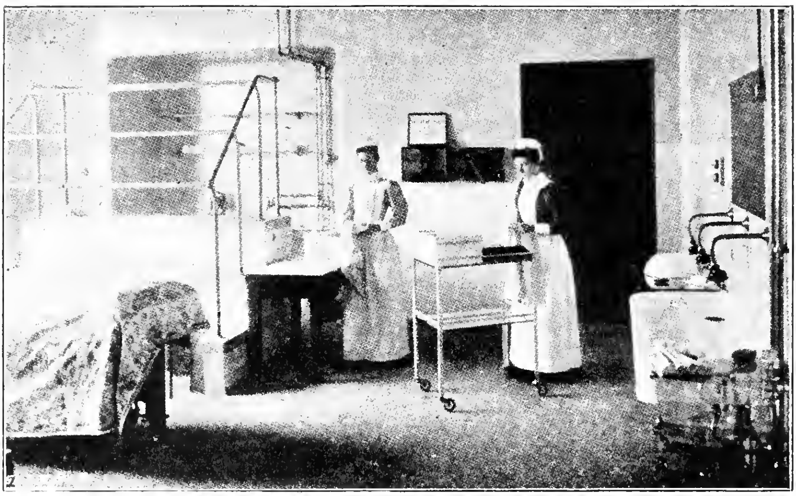
The third international ophthalmologic congress was held at Paris, Aug. 12-14, 1867 (not, as originally intended, at Vienna in 1866).

The fourth met in London in September, 1871. The fifth, in New York City, in 1876. The sixth, at Milan, in 1880. The seventh, at Heidelberg, in honor of the five-and-twentieth anniversary of the founding of the Heidelberger Ophthalmologen-Gesellschaft—the first of all local ophthalmologic societies—in September, 1888. The eighth

[22] The first international congress of a general medical character met in 1867, just ten years later.

was held at Edinburgh in 1894, the ninth at Utrecht in 1900. The tenth at Lucerne in 1904. The eleventh at Naples in 1909. The twelfth was intended to be held at St. Petersburg in 1914, Aug. 10 to 12, but was, of course, as many have reason to remember, prevented from occurring by the sudden and terrific outbreak of the war.

The first local ophthalmological society was the Heidelberg Ophthalmological Society, which was founded by von Graefe in 1863.[23] In 1888, as already stated, it celebrated the 25th year of its existence by



Operating Theatre at Moorfields Eye Hospital, London.

the convocation at Heidelberg of the seventh international "Ophthalmologen-Congress."

The British Medical Association was instituted in 1836, but the first ophthalmological society (the British Ophthalmological Society) was not instituted till 1880. Two of its founders were Nettleship and Bowman, and Bowman was its first president. There is also now an ophthalmic section of the Royal Society of Medicine.

Journals.[24]

Germany and Austria.—The first ophthalmic journal in any country was founded at Braunschweig and Jena in 1801 by Carl Himly and

[23] Just a trifle earlier than the American Ophthalmological Society, which was instituted in January, 1864.

[24] For a complete discussion of ophthalmic journals, see, in this *Encyclopedia*, **Ophthalmic Literature.**

Johann Adam Schmidt, under the name of "*Ophthalmologische Bibliothek.*" This journal died in 1807. It was, however, in 1816, revived by Himly alone at Hannover, under the slightly altered title of "*Bibliothek für Ophthalmologie.*" This journal, like its predecessor, was short lived, passing away in 1819. The next German periodical was C. F. von Graefe and Walther's "*Journal der Chirurgie und Augenheilkunde,*" founded in 1820, which ran through a course of thirty volumes in twenty years, expiring in 1840. Three years later it was resuscitated by Walther and von Ammon, and lived then for seven years (nine volumes). From 1830 to 1836 appeared the "*Zeitschrift für Ophthalmologie,*" and, from 1836 to 1840 the "*Monatschrift für Medicin, Augenheilkunde und Chirurgie.*" In 1854, Albrecht von Graefe, together with Arlt and Donders began to publish the "*Archiv für Ophthalmologie,*" commonly known as "von Graefe's *Archives.*" This extremely valuable journal is still in process of appearance and is very prosperous. In 1862 appeared Zehender's "*Klinische Monatsblätter für Augenheilkunde,*" in 1869 the "*Archiv für Augen- und Ohrenheilkunde*" of Moos and Knapp, which ten years later, was divided into the "*Archiv für Augenheilkunde*" (edited by Knapp and J. Hirschberg, Berlin) and the "*Archiv für Ohrenheilkunde*" (edited by Knapp and Moos). An edition in English was published from the very beginning of each of these three periodicals. In 1870, at Tübingen, was founded the "*Jahresbericht der Ophthalmologie*" by Nagel, who, however, was soon succeeded as editor by Michel. Eight years later appeared the "*Centralblatt für Praktische Augenheilkunde*" of Hirschberg, at Berlin.

France.—The earliest ophthalmic periodical in the French language was founded by Florent Cunier, "the father of Belgian ophthalmology," at Brussels, in 1838. It was called the "*Annales d'Oculistique.*" From 1853 till 1855 appeared, beneath the guidance of Jamain, the "*Archives d'Ophtalmologie,*" at Paris; in 1872 the "*Recueil d'Ophtalmologie,*" of Galezowski, and, in 1881, the "*Archives d'Ophtalmologie*" again. In the following year was founded at Paris, by Meyer and Henri Dor the "*Revue Générale d'Ophtalmologie.*"

England.—The first ophthalmic periodical in England was (to have been) entitled "*The Journal of Ophthalmology,*" and was (to have been) published by Richard Middlemore in 1837. According to Pansier (*Histoire de l'Ophtalmologie*, in *Enc. française d'Ophtalmologie*, Vol. I, 1903, p. 56) this journal lived one single year. The sad truth is, however, that such a journal never saw the light at all, for Middlemore merely published (in 1836, not 1837) a plan, or prospectus, of the "Journal" in question. The journal itself was never born. In

1857 began to appear "*The Ophthalmic Hospital Reports and Journal of the Royal London Ophthalmic Hospital,*" current until the recent merger with other journals to form, under the editorship of Mr. Sydney Stephenson, "*The British Journal of Ophthalmology.*" In 1865 "*The Ophthalmic Review*" was founded at Manchester, by J. Zachariah Lawrence and Thomas Windsor. It lived three years. Next came the *second* "*Ophthalmic Review,*" published at London in 1882, and founded by Carl Grossmann, of Liverpool, and Priestley Smith, of Birmingham. In 1903 was founded "*The Ophthalmoscope,*" by Sydney Stephenson, of London, and Charles A. Oliver, of Philadelphia. This later became an exclusively English publication. In 1916 "*The Ophthalmoscope,*" "*The Ophthalmic Review,*" and the "*Royal London Ophthalmic Hospital Reports*" were merged to form a new publication of enormous value, "*The British Journal of Ophthalmology.*" [25]

Italy.—Ophthalmic journalism in Italy began with the founding by Borelli, in 1858, of the "*Giornale d'Oftalmologia Italiano.*" In 1891 the "*Annali di Oftalmologia*" was founded by Quaglino.

The "*Wiestnik Oftalmologii*" of Chodin, was founded at Kiew in 1884.

Today there are more than ninety ophthalmic periodicals appearing in various portions of the world.

Text-Books.[26]

In order to present a connected treatment of this subject, we have heretofore reserved the topic of ophthalmic text-books until the discussion of the 19th century—chiefly because the ophthalmic text-book, though indeed it came into existence under the hands of the old Arabian, Jesu Haly, about 1040 or 1050, yet was practically dead, buried and unheard of from then till the 16th century, and only arose to a conscious and lasting existence just about the beginning of the 19th. We shall therefore, as we write of the books of each of the more important countries, speak, first, a little of the works of that country which appeared in the 16th, 17th, and 18th centuries.

Germany.—The earliest German (as well as the earliest modern) treatise [27] on the eye was published, as we have said when speaking

[25] A similar merger of American journals is at present under way, beneath the guidance of Dr. Edward Jackson, editor of "*Ophthalmic Literature.*"

[26] For a complete discussion of ophthalmic treatises, see, in this *Encyclopedia,* **Ophthalmic Literature.**

[27] By which I mean, of course, in the German language, as well as published in Germany. The work of Leonhart Fuchs (1539), *Tabula Oculorum Morbos Com-*

of the 16th century, by Georg Bartisch, of Dresden, in 1583, just three years earlier than the earliest English treatise. By the 19th century, the works of German ophthalmographers were getting to be pretty abundant. The earliest to be written in the century now under consideration was that by Carl Himly, entitled "*Lehrbuch der Praktischen Heilkunde*" (Göttingen, 1807). This, however, was not published till 1843. Weller, in consequence, may truly be said to lead the ophthalmology of the 19th century, in German, with his "*Krankheiten des Menschlichen Auges*" (Berlin, 1819; 2d ed., 1822; 3d ed., 1826). Weller, at the time of the first edition of his book, was only 25 years of age, and yet so exceedingly excellent was his work that it soon became a high, perhaps the highest, authority in Continental Europe. Next came Benedict's "*Handbuch der Praktischen Augenheilkunde*," an enormous affair, in five large volumes, published at Leipsic from 1822 to 1825. The style of the work, however, is bad, and the book as a whole, even according to Hirsch and Hirschberg (who here for once agree) is little in advance of the "*Lehre von den Augenkrankheiten*," of Joseph Beer, the first edition of which had appeared in 1792. Next after Benedict's volumes followed the very useful, "*Handbuch der Theoretischen und Praktischen Augenheilkunde*," of Anton Rosas (3 vols, Vienna, 1830). Jüngken, in 1832, put forth "*Die Lehre von den Augenkrankheiten*," etc. Andreae, in 1834 and 1837, his "*Grundriss der Gesamten Augenheilkunde*" in two parts, both of which were popular. Not a large book, but clear, succinct and interesting, it has been pronounced by no less an authority than Magnus "the best ophthalmic text-book of the pre-ophthalmoscopic period." Ruete, in 1842, published his excellent "*Lehrbuch der Ophthalmologie*," while four years later appeared the "*Lehrbuch der Gesamten Entzündungen und Organischen Krankheiten des Menschlichen Auges*," etc., of Johann Nepomuk Fischer, "The Father of ophthalmology in Bohemia." The work was never popular, and yet it was thorough, practical and clear. In 1859 appeared Winther's "*Lehrbuch der Augenheilkunde*," a work which met with little favor. Arlt's great book, "*Krankheiten des Auges*" (3 vols., 1851, 1853, and 1856) was well received by specialists, and, from this time on, the German treatises on ophthalmology were far too numerous to be recorded here, saving and excepting, of course, the "*Lehrbuch der Augenheilkunde*" of Ernest Fuchs, which has run through many editions and translations, and is one of the greatest favorites in every portion of the globe.

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prehendens, was, as its title suggests, in Latin. "The last Latin ophthalmology," too, the *Doctrina de Morbis Oculorum*, of Johann Gottlieb Fabini (Pesthini, 1823), is, for the same reason, excluded.

Of German "systems" of ophthalmology, we have, naturally, to record the colossal Graefe-Saemisch "*Handbuch der Gesamten Augenheilkunde,*" which appeared from 1874 to 1880, in seven large volumes, under the editorship of Alfred Graefe and Theodor Saemisch. A second, greatly enlarged, edition of this work began to appear in 1898, and, when complete, will consist of fifteen large octavo volumes. A third edition was begun in 1910, therefore in advance of the completion of the second edition. There was also a German "*Encyclopedie der Ophthalmologie.*" This began to appear in 1902, and ran to the letter S, in 1909, since which time there have appeared, so far as I have been able to learn, no further volumes.

England.—In England the little book of Richard Banister, "*A Treatise of 113 Diseases of the Eyes and Eyelids*" (London, 1622), is, as a rule, accredited with being the earliest treatise on ophthalmology to appear in the English language. The work, however, is very little more than a bare translation of Guillemeau's "*Des Maladies de l'Oeil,*" plus a few brief doggerel "poems." In 1626, however, appeared a work by Walter Bailey, entitled "*Directions for Health, Natural and Artificial, with Medicines for all Diseases of the Eyes,*"[28] a work which is now extremely rare.

The principal ophthalmic treatises in 18th century England were the following: William Coward's "*Ophthalmiatria*" (London, 1706), which is scanty and poorly written. Sir William Reed's "*Treatise of the Eye Containing a Short but Exact Description of the Structure, Situation . . . as also the Causes, Symptoms and Cures of 130 Diseases Incident to Them*" (London, 1706) which seems to be no longer extant. Peter Kennedy's "*Ophthalmographia*" (London, 1713) and a "*Supplement*" thereto (London, 1739). John Hill's "*The Fabric of the Eye and the Several Disorders Who* [*sic!*] *Obstruct the Sight*" (London, 1758). Joseph Warner's "*A Description of the Human Eye and its Adjacent Parts; Together With Their Principal Diseases and the Methods Proposed for Relieving Them*" (London, 1773). William Rowley's "*Treatise on the Principal Diseases of the Eyes*" (London, 1773). George Chandler's "*A Treatise*

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[28] Bailey had published in 1586 the first edition, and in 1616 the second edition of a book entitled "*A Brief Treatise of the Preservation of the Sight,*" which, however, is a work confined exclusively to the subject of ocular hygiene. We are here considering not ocular monographs at all, but general works, or treatises, on ophthalmology.

All ocular monographs of the 19th century which here we have the space for are, as in the case of all the other centuries, mentioned in connection with the innovations which they introduced. Ophthalmic treatises, however (nearly all of which have appeared in the 19th and 20th centuries), could not thus easily be disposed of.

on the Diseases of the Eye," etc. (London, 1780). William Rowley also wrote a "*Treatise on One Hundred and Eighteen Principal Diseases of the Eyes and Eyelids*" (London, 1790).

Not one of these works, however, was really an adequate treatise. It remained for the England of the 19th century to supply a great ophthalmic literature.

The earliest general work on ophthalmology in the English language to appear in the 19th century was that of Benjamin Travers, entitled "*Synopsis of the Diseases of the Eye and Their Treatment*" (1820; 2d ed., 1821; 3d ed., 1834; Amer. ed., 1825; It. trans., Pisa, 1823). This was the greatest work on ophthalmology in the English language to and including its time. It soon, in fact, became an authority in America and on the continent of Europe. In the same year appeared John Vetch's "*A Practical Treatise on the Diseases of the Eye*" (London, 1820), a far inferior work. Next came William Mackenzie's clear, succinct and comprehensive "*Practical Treatise on Diseases of the Eye*" (London, 1830; 2d ed., 1835; 3d ed., London, 1840; 4th ed., 1854; Fr. trans. 1844 and 1856; Amer. Reprint at Boston, 1833 and at Phila., 1855).

After Mackenzie's book, the principal works were as follows: Wm. Lawrence's "*A Treatise on the Diseases of the Eye*" (London, 1833) a work which was based upon its author's lectures at the London Ophthalmic Institute. John Walker's "*The Principles of Ophthalmic Surgery*" (London, 1834) a work which, spite of its name, is a treatise on all-round ophthalmology. Richard Middlemore's "*A Treatise on the Diseases of the Eye and its Appendages*" (2 vols., London, 1835), declared by Julius Hirschberg to be "the most comprehensive text-book on ophthalmology which the English literature of the first half of the 19th century affords." Frederick Tyrrel's "*A Practical Work on the Diseases of the Eye and Their Treatment, Medically, Topically, and by Operation*" (2 vols., London, 1840). James Dixon's "*A Guide to the Practical Study of Ophthalmology*" (London, 1855), which was far behind its day, containing in fact no reference to ophthalmoscopy. Soelberg Wells's "*A Treatise on the Diseases of the Eye*" (London, 1869; 2d ed., 1870; 3d ed., 1873), a favorite work in foreign lands, especially America. Edward Nettleship's "*Student's Guide to Diseases of the Eye*" (London, 1879, and numerous later editions) a small but excellent work, which has acted as "guide" indeed to thousands of medical students in America, as well as in Great Britain and all the English-speaking countries. Last of all that here we may mention, Henry M. Swanzy's "*A Handbook of the Diseases of the Eye and Their Treatment*" (London, 1884; 10th ed. in 1912).

Also a small but excellent affair, which equals in popularity the compendium of Nettleship.

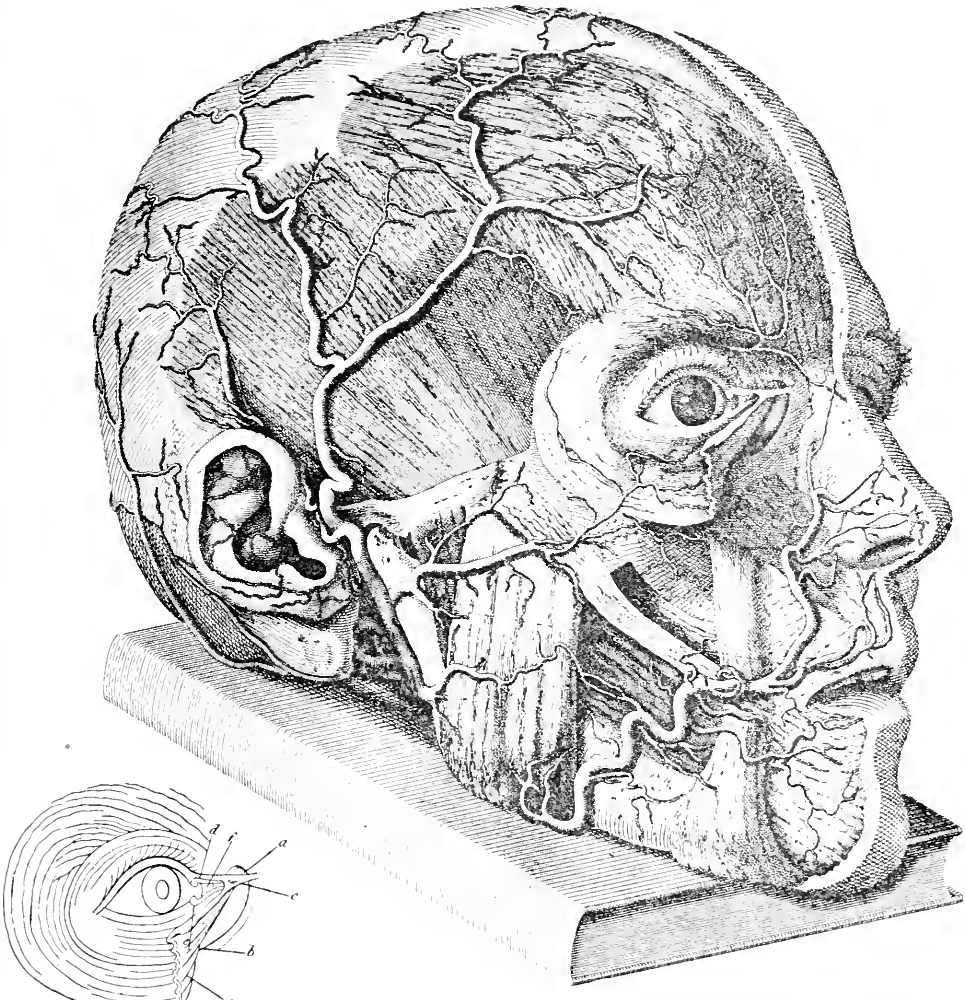
France.—The earliest ophthalmic treatise in French was that of Maître-Jan, called "*Traité des Maladies de l'Oeil et des Remèdes Propres pour leur Guérison*" (Troyes, 1707; Paris, 1722; 1741), an excellent work for a beginning. Next came a still more useful book, St. Yves's "*Nouveau Traité des Maladies des Yeux*" (Paris, 1722). Then followed, at an interval of almost half a century, Dehais-Gendron's "*Traité des Maladies des Yeux et des Moyens et Opérations Propres à leur Guérison*" (2 vols., Paris, 1770). Dehais-Gendron, it will be remembered, was the first incumbent of a chair devoted exclusively to ophthalmology. His book remained in favor for more than 40 years. The century, then, was closed by a somewhat insignificant and impractical volume by Desmonceaux, called "*Traité des Maladies des Yeux et des Oreilles Considerés sous le Rapport des Quatre Ages de la Vie de l'Homme*" (Paris, 1786).

Perhaps the earliest of the 19th century treatises in France were those of Roux (1820), Delarue (1820) and Demours (1821). These, however, were exceedingly incomplete and by no means up to date. Even Pansier writes (*Enc. franç. d'oph.*, I, p. 54): "En effet, le traité de Pierre Demours n'est qu'un brillant reflet du XVIII^e^ siècle celui de Delarue (1821) est en plus très incomplet."

The earliest French ophthalmic treatise of the 19th century, possessed of any particular value, was written by Victor Stoeber (1803-1871), and was called "*Manuel Pratique d'Ophtalmologie ou Traité des Maladies des Yeux*" (Paris and Strassburg, 1834; reprint, Brussels, 1837). Though not entirely abreast of the ophthalmic science of its day, it was clear, concise and complete. Rognetta, in 1839, published at Paris his "*Cours d'Ophtalmologie ou Traité Complet des Maladies de l'Oeil,*" etc., an excellent volume and fully up to date. Not quite so good was Tavignot's "*Traité Clinique sur les Maladies des Yeux,*" which appeared at Paris in 1847. The best of all, to its time, however, was Desmarres's "*Traité Théorique et Pratique des Maladies des Yeux*" (pp. 904, with 78 figures intercalated in the text; Paris, 1847; Ger. trans. by Seitz and Blattmann, Erlangen, 1852; 2d French ed., 3 vols., 1854-58). This was a very remarkable textbook, the best, in fact, that had ever appeared in any language at the time of its publication. In 1862 there was published the first French treatise of the post-ophthalmoscopic period—that of Deval, entitled "*Traité Théorique et Pratique des Maladies des Yeux*" (pp. 1056, 6 colored illustrations, 3 plates of instruments and 44 figures in the text). The work does ample justice to the later developments of

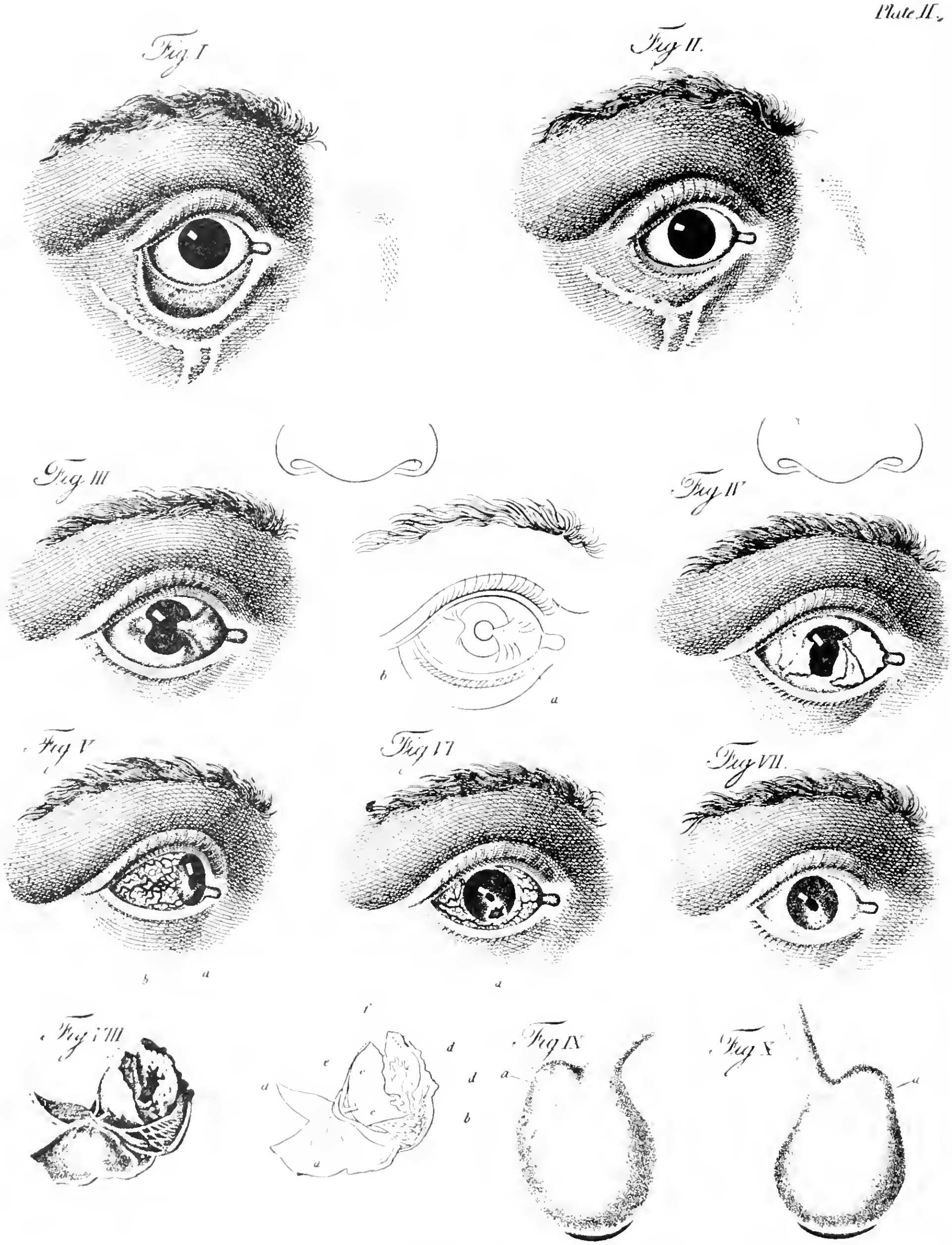
ophthlamology—the ophthalmoscope, the various diseases of the fundus, the testing of visual acuity, etc.

From this time on, the list of French ophthalmic treatises is much

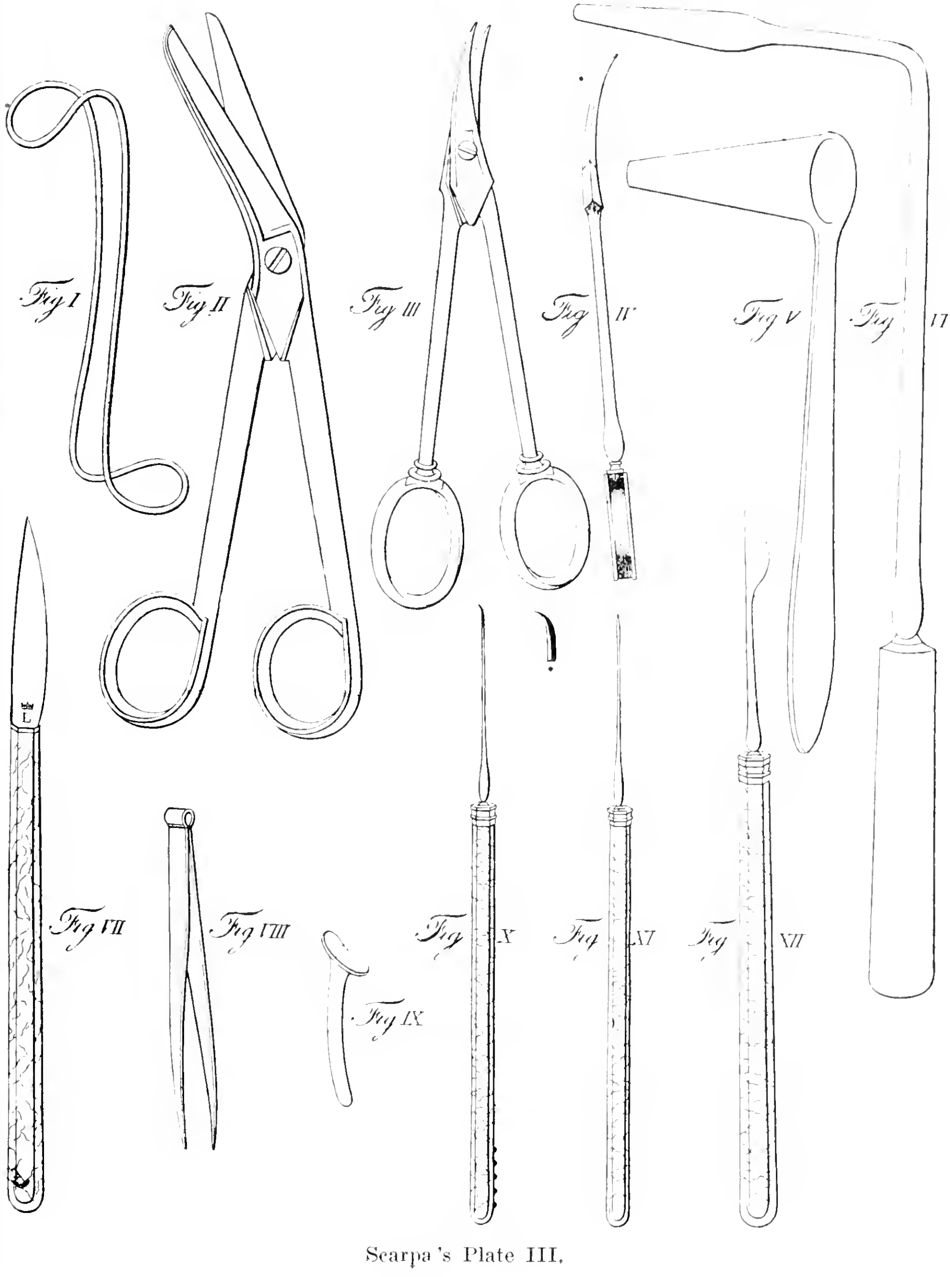


Scarpa's Plate I.

too large for presentation here. We will, however, close by recalling to the reader's mind the monumental "*Encyclopédie Française d'Ophtalmologie*," of Lagrange and Valude (9 large octavo volumes, Paris, 1903-10).



Scarpa's Plate II.



Scarpa's Plate III.

Italy.—The earliest Italian treatise on ophthalmology was that of Domenico Billi, "*Breve Trattato delle Malattie degli Occhi di Domenicho Billi, Cerusico d'Ancona,*" etc. (Ancona, 1749, pp. 224, with a plate). In the preface to his work, this early Italian ophthalmographer sets forth the reasons which he had for the composition of the book. The Italian surgeons, he says, understand no English, French, or German; hence, they are far behind the world beyond the Alps in all that pertains to the theory and practice of ophthalmology. Hence, too, the poor of Italy who suffer from diseases of the eyes, must submit themselves to the blind leading of peripatetic quacks. Though the work professes to be but the merest compilation from German, French, and English ophthalmologists, it is nevertheless

PLATE I.

a, b. The lachrymal ſac.

c. The tendon or ligament of the *orbicularis* muſcle of the eye-lids.

d. The ſuperior lachrymal punctum.

e. The inferior lachrymal punctum.

f. The caruncula lachrymalis.

g. A portion of the orbicularis palpebrarum which covered the lachrymal ſac, ſeparated in a great meaſure from the ligament c. and everted.

PLATE II.

Fig. 1. The everſion of the lower eye-lid, occaſioned by a ſhortening of the integuments, in conſequence of an extenſive cicatrix formed a little below it.

Fig. 2. The ſtate of the lower eye-lid (fig. 1.) after the operation. In conſequence of the greater ſhortening of the integuments towards the temples than the noſe, the lower eye-lid is ſeen to be leſs elevated towards the external than the internal angle. It embraced the lower part of the eye-

6 ball

Scarpa's Explanation of his Plates.

ball however, fufficiently to prevent the defcent of the tears upon the cheek, and to correct the deformity.

Fig 3. Two ptervgia of different fizes upon the fame eye, taken from a dead fubject.

a. The larger pterygium fituated upon the eye-ball on he fide next the nofe.

b. The fmaller pterygium on the fide next the temples. The two lines, one ftraight, the other femicircular, marked upon the pterygium a, denote the double direction which ought to be given to the incifion in the extirpation of the difeafe.

Fig. 4. Diffection of the conjunctiva of the eye (fig. 3.) which evidently proves that the pterygium is nothing more than a morbid thickening of the fine lamina of this membrane, which naturally covers the external furface of the cornea.

Fig 5. a. The nebula of the cornea.

b. The fafciculus of varicofe blood veffels of the conjunctiva, by which the nebula of the cornea is, as it were, nourifhed and kept up.

Fig. 6. a. Procidentia of the iris through a fmall ulcer of the cornea. In this figure is feen the whitifh margin of the ulcer, the contracted and preternaturally difplaced ftate of the pupil, and the oblong figure which it affumes in fuch cafes.

Fig. 7. The ftate of the eye (fig. 6.) after the cure of the procidentia of the iris. The pupil in fome degree recovers its natural figure.

Fig 8. Calculous concretion of the internal part of the eye.

a. a. The fclerotica turned back.

b. A portion of the choroidea.

c. c. Calculous concretion in the form of a fmall cup or *fcutella*, which occupied the bottom of the eye precifely in the fituation of the vitreous humour.

d. d. The

d. d. The other calculous concretion in the ſituation of the corpus ciliare.

e. The entrance of the optic nerve into the cavity of the eye-ball through the centre of the calculous ſcutella c. c.

f. The ſoft funnel-ſhaped body, which extended from the bottom of the eye as far as the ſituation of the capſule of the cryſtalline lens.

Fig. 9. Staphyloma of the ſclerotic and choroid coats ſituated at the bottom of the eye.

Fig. 10. Another ſtaphyloma of the ſclerotic and choroid coats ſimilar to it.

PLATE III.

Fig. 1. An elevator for the upper eye-lid.

Fig. 2. Crooked or probe-ſciſſion for the diviſion of the integuments of the eye-lids in caſes of Trichiaſis, or of exceſſive relaxations of them.

Fig. 3 Small ſciſſors very convenient for removing any portion of the internal part of the eye-lids, or of the conjunctiva.

Fig 4. Sciſſors curved upon the back, commonly called by the French *ciſeaux à cuiller*.

Fig. 5 6. Apparatus for cauterizing the os unguis and pituitary membrane which covers this bone on the ſide of the cavity of the noſtril.

Fig. 7. Small knife for the diviſion of the cornea.

Fig. 8. Forceps very uſeful in the various operations which are performed upon the eye-lids, conjunctiva, and eye-ball.

Fig. 9. A ſolid leaden tent, furniſhed with a ſmall plate, for the purpoſe of compreſſing the external part of the lachrymal ſac.

Fig

EXPLANATION OF THE PLATES.

Fig. 10. The needle with a curved point, for the depreſ-ſion of the cataract.

* The point of the inſtrument magnified.

Fig. 11. The ſame needle with a ſtraight point.

Fig. 12. A ſmall convex-edged biſtoury, very uſeful in removing the fungoſities of the internal ſurface of the eye-lids, and encyſted tumours of thoſe parts.

Scarpa's Explanation of his Plates.

well written, and, in the words of Hirschberg, "For the development of ophthalmology it has certainly been of value."

Next in Italy came the "*Lezioni Intorno alle Malattie degli Occhi*" (Naples, 1780; 463 pp. and 2 plates) of Michele Troja, a work that was fully abreast of its time and, in many ways, of value.

The earliest Italian text-book of the 19th century was that of Antonio Scarpa,[29] the father of Italian ophthalmology. It is called "*Saggio di Osservazioni ed Esperienze sulle Principali Malattie degli Occhi*" (Pavia, 1801; later eds., 1805, 1811, 1817, 1836; Ger. trans., Leipsic, 1803, 2d ed., 1823; Eng. trans., London, 1806, 2d ed., 1818; French trans., Paris, 1802, 2d ed., 1807, 3d ed., 1811; French elaboration by Fournier Pescay and Bégin, Paris, 1839; Dutch trans., Groningen, 1812). In this memorable book the distinguishing features are, a clear and almost brilliant literary style, greatly bettered definitions of ophthalmologic technicalities, and a well-marked tendency to the practical application of the then known anatomy, pathology, and optics. The book was a high authority throughout the civilized world for a double decade.

The next Italian work on the eye was Giovanni Battista Quadri's "*Annotazioni Pratiche sulle Malattie degli Occhi Raccolte nella Reale Scuola Clinica di Napoli*" (2 vols., Naples, 1818-24). Other early Italian works of a general ophthalmic character are those of Asson, at Venice, in 1842-45; of Cappelletti, at Trieste, in 1845; and of Gioppi, at Padua, in 1858. Still later treatises are very numerous indeed.

The beginning of ophthalmic literature in Holland was formed, precisely as in England, by a translation (Carolus Battus *fecit*) of Guillemeau's "*Traité des Maladies de l'Oeil qui Sont en Nombre de*

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[29] Scarpa, it should also be remembered, discovered "Scarpa's triangle," the naso-palatine nerve, and the "true posterior staphyloma of Scarpa."

Cent Treize, Ausquelles il est Suject." The work was published at Dordrecht by Abraham Caen in 1597.

It is absolutely obvious that any attempt at a complete ophthalmic bibliography would not be here in place: the room (for a single reason) is very largely lacking, and, again, a *list* of books or monographs, or of journals and articles, makes rather *listless* reading. Let us turn, therefore, from the literature of our specialty to the substance, the very subject-matter of the art itself: ophthalmic anatomy, physiology and diagnosis, pathology, prophylaxis, therapy and treatment. The subject is, of course, too large for an extensive treatment here. We shall, however, attempt to exhibit these various ophthalmic matters in a brief, and, as it were, a vanishing outline—vanishing, that is to say, or at least considerably diminishing, as we approach the present moment—for the ophthalmology of the last double, or even treble, or quadruple decade, is to be found in full in the non-historic portions of this *Encyclopedia.*

Even by the use of the "brief and vanishing outline," we shall have much trouble in presenting our enormous quantity of subject-matter with any degree of clarity and cohesion. So great, in fact, and so extremely numerous also, are the changes which now we are going to notice in the greatest of all the centuries, that it seems to be advisable, before we begin our journey through that marvelous hundred years, to take (as an accurate point of departure, by which, at any given moment, the distance which we have traversed can properly be judged) a kind of inventory of the science and art of ophthalmology as these existed at the threshold of the period. This we may easily do by providing a summary, or, better, a commentated abstract, of the "*Saggio di Osservazioni e d'Esperienze sulle Principale Malattie degli Occhi*" of Antonio Scarpa, the first edition of which appeared, as we have said, in 1801, and which was surely the greatest text-book that had ever been published in any land or time. The only edition of the work, however, which I have employed in the making of the summary is Briggs's English translation of the first edition, a highly valued rendering which appeared at London in 1806.

Scarpa's book, then, is divided into a preface and 20 chapters. Discarding the superfluous and decidedly loquacious and circumstantial preface, we take up each of the chapters *seriatim:*

Chap. I. Of the Puriform Discharge of the Palpebræ and Fistula Lachrymalis.

Dacryocystitis, we may say at the beginning, was thoroughly confounded by the surgeons of Scarpa's time (who called it "the fistula lachrymalis") with purulent conjunctivitis. Thus, our author says that, by the general agreement of surgeons, "A *fistula lachrymalis* exists, whenever a discharge of a viscid, curdly, yellowish matter, resembling pus and mixed with tears, issues from the *puncta lachrymalia*, on compressing the space situated between the internal canthus of the eye and the nose." Scarpa himself, however, believes in a certain distinction: "Whenever, therefore, on pressing the lachrymal sac, though in other respects in a sound state, a viscid, curdly, yellowish matter, resembling pus, flows from the *puncta lachrymalia*, I give to that morbid state of the *via lachrymalia* the appellation of the puriform discharge of the palpebræ; and I would restrict the term *fistula lachrymalis* to that form of disease, in which the lachrymal sac is not only greatly distended, but ulcerated, and in a fungous state on its internal surface, where there is likewise an external opening, which is sometimes accompanied with a caries of the *os unguis*." From "the puriform discharge of the palpebræ" he then proceeds to exclude the disease of the lids "arising from the application of the matter of gonorrhea."

His treatment of the puriform disease of the palpebræ is, in the earlier stages, the ophthalmic ointment of Janin.[30] In a later stage of the affection, when the internal membrane of the palpebræ presents a villous appearance, he uses, in addition to Janin's ointment, the unguentum nitratis hydrargyri of the Edinburgh *Pharmacopeia*, or, if necessary, the argentum nitratum of St. Yves. To keep a permeable canal, he injects the lachrymal passages with distilled plantain water.

When the disease is in the second stage, especially if it be accompanied by distention of the lachrymal sac, he incises the sac longitudinally, and passes a probe down through it into the nose. Removing the probe, he passes in its place a bougie, which he leaves for a long time *in situ*. If this does not suffice, he uses escharotics in the sac. Ulceration follows, and, in the healing process, a certain degree of contraction occurs in the sac wall.

The third stage of the disease, he says, is a *true fistula lachrymalis*.

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[30] Take of hog's lard half an ounce, prepared tutty and armenian bole, of each two drams, white precipitate (calx hydrarg. alba), a dram. The hog's lard, having been washed three times in rose water, should be intimately mixed in a glass mortar, with the other ingredients previously reduced to a fine powder.—*Scarpa.*

An abscess forms of the saccular parietes, which perforates the substance of the sac, and discharges externally. The treatment consists in artificial opening (in case spontaneous perforation has not yet happened) and then the use of escharotics.

"The fourth stage of the puriform discharge of the palpebræ," he then goes on to say, is "commonly called by surgeons *fistula lachrymalis cum carie*." It exists in two forms. In the first, a passage is eroded through the *os unguis* into the corresponding nostril. In the second, the fistula forms externally through the skin, while, simultaneously, the *os unguis* is "denuded and carious, but not perforated." The first of these conditions may be cured by laying the sac wide open and applying escharotics, while the lids themselves are treated, as well as the general mal-condition of the patient. In the second of the forms he recommends that an artificial passage be produced *via* the *os unguis* into the nose [31] —The passage, he rightly says, soon closes up spontaneously.

Chap. II. Of the Hordeolum.

"The hordeolum, strictly speaking, is only a small bile [*sic*] which forms upon the margin of the palpebræ, most frequently towards the great angle of the eye." After a distinction of the disease into two main heads, or varieties—the first, *furuncular*, which commences in the skin and extends to the cellular tissue, and the second, or *phlegmonous*, which begins in the cellular tissue and thence is propagated to the skin—he expounds the treatment of hordeolum as follows: Incipient furuncular hordeolum, i. e., an hordeolum which still is only in the skin, he "repels" by means of cold, applied in the form of a coin or other piece of metal, or a bit of ice. In the second stage, however (i. e., when the cellular tissue has begun to be affected) the parts are only harmed by cold, and so a poultice of bread and milk, well heated, and mixed with a little melon-pulp, or saffron, should be applied, and renewed each second hour. The abscess, then, will point spontaneously, and even discharge of itself; but, if necessary, an incision may be made.

Scarpa did not know at all, as it seems, that a stye may be either induced or continued by an error in the optical apparatus of the eye.

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[31] A procedure which, though absolutely useless, has been revived as an original operation in the last three, or, say, four, decades, a considerable number of times.

Chap. III. Encysted Tumors of the Eye-Lids.

By "encysted tumor" Scarpa means what today is called by the ancient name, "chalazion." These tiny tumors he extirpates, and, indeed, as a rule, from the inner surface of the lids, as is the custom at the present day. Chalazion forceps and curette, however, were alike unknown to him. He simply excised the sac by means of curved scissors, cauterizing then with silver nitrate.

Chap. IV. Of the Cilia which Irritate the Eye.

This disease, which is termed "trichiasis," is, as a rule, accompanied by a curving inward of the tarsus. In fact without this inward curving, the disease is very rare. When the tarsus is curved inward, the curving may be either complete or incomplete—i. e., it may affect the tarsus as a whole or its free edge only. The author goes on to say that, to these two kinds of trichiasis some authors add a third, called "*distichiasis,*" which they suppose to be produced by a double and unusual row of hairs. On this he truly observes (but later writers have not heeded): "But this third species is only imaginary, and the reason of such subdivision seems to have arisen from a want of recollecting what was long ago remarked by Winslow and Albinus on the natural arrangement of the cilia; that although their roots appear to be disposed in one line only, they nevertheless form two, three, and in the upper eye-lid even four ranges of hairs, unequally situated, and as it were confused. Whenever, therefore, in consequence of disease a certain number of hairs are separated from each other in a contrary direction and disorderly manner, the eye-lash will appear to be composed of a new and unusual row of them, while in fact there has been no change either with respect to their number or natural implantation."

After condemning the mere avulsion of the hairs, with or without after-treatment by the cautery, he thus proceeds to expound the proper means for the radical cure of trichiasis: "The most efficacious method for the complete cure of this disease, which has been hitherto employed, not excluding that recommended by Kokler, and known as far back as the time of Rhases [and he might have said, Galen and Celsus] consists, as I have already stated, in the excision of a certain portion of the skin of the affected eye-lid, close to the tarsus. . . . The surgeon should . . . then with the forceps, or with the point of the forefinger and thumb . . . raise a fold of the integuments . . . being particularly careful that the part taken hold of corresponds exactly to the middle of the space occupied by the trichiasis. . . . Particular

attention should be paid that the division of the skin be made sufficiently near the inverted tarsus. Without attention to this circumstance, the surgeon may be disappointed after the healing of the wound to find the eye-lid shortened upon the whole from the eye-brow to the place of excision, but not in an equal proportion in the space between the edge of the eye-lid and the cicatrix of the integuments; consequently, the tarsus will remain folded inwards as before, or not sufficiently everted to prevent the hairs from coming in contact with the eye; which inconvenience would subject the patient to a second excision of the integuments of the eye-lid lower than the first."

Conspicuous by their absence, to any modern reader, are the methods of Flarer, Arlt, Jaesche, Snellen, Hotz, Oettingen, etc., which make the surgery of trichiasis a vastly different thing today. Scarpa, in fact, was little if at all, with regard to the matter in question, in advance of the times of Galen.

Chap. V. Of the Relaxation of the Upper Eyelid.

According to Scarpa, a relaxed upper eyelid may be (a) congenital, or (b) produced by (1) obstinate chronic ophthalmia (2) the long continued use of emollient and relaxing applications (3) an atony of the elevator muscle, either simple or accompanied by a paralysis of the optic nerve (4) a spasm (at intervals) of the orbicular muscle of the eyelids.

His treatment is as follows: "When the disease is purely local and recent, in persons not advanced in age, etc." he expects advantage from the use of local corroborant remedies—cold water, with a small addition of alcohol, friction to the eyelid, cantharides. In cases caused by hypochondriasis, hysteria, or the like, he uses with much success "internal antispasmodic and antihysteric remedies . . ., emetics and anthelmintics." Mostly, however, he cures by operation, precisely as in trichiasis.

Chap. VI. Of the Eversion of the Eyelids.

This, he says, is commonly termed *ectropion*. It exists in two varieties: "the one arising from a preternatural tumefaction of the palpebræ," the other from a shortening of the skin which covers the lid or some of the neighboring parts.

In the first variety of the disease he destroys "the superficial fungus of the internal membrane of the eyelid with the argentum nitratum, or if the disease is found to be considerable, extirpates the fungus, more or

less completely, according to the state of the case, with the curved "scissars." In the second species of eversion, though in its manner of causation the very opposite of the first, precisely the same procedure, as a rule, may be applied with much success—i. e., the extirpation of a portion of the lining membrane of the lid.

Scarpa then proceeds to condemn "the division of the cicatrices of the integuments, which have given rise to the contraction and eversion of the eyelid, does not produce a permanent elongation of it, and therefore is attended with no advantage in the treatment of this disease." From which it appears that the science and art of blepharoplasty was practically unknown.

Chap. VII. Of the Ophthalmia.

Of this disease our author distinguishes two varieties—*calida* and *frigida*—the first "arising from an excess of stimulus and reaction of the living solid; the other chronic. from debility which is most frequently confined to the vessels of the eye or those of the eyelids, but occasionally is connected with a weakness of the general constitution at the same time." Each of the kinds may be acute or chronic.

For mild acute ophthalmia he employs a proper regimen, purgation (gentle) "with a grain of the antimonium tartarizatum dissolved in a pint and a half of the decoction of the root of the triticum repens" together with external applications to the eyes of "aqua malvæ made tepid, and . . . bags of emollient herbs boiled in new milk." For the violent acute cases, he recommends venesection highly, and "the circular excision of the projecting portion of the conjunctiva with the curved scissars, at the part where the cornea and sclerotica unite."

Scarpa next interpolates a description (together with the treatment) of a special kind of acute inflammatory ophthalmia, as follows: "I cannot, however, omit to mention a particular species, of the violent acute ophthalmia, which is distinct from the common in this respect, that although the inflammation and swelling of the eyelids and conjunctiva come on with great intensity, like the other cases of ophthalmia of this species; yet a short time afterwards it is attended with an extraordinary copious discharge of matter from the eyes of a puriform appearance. This disease, as it is most commonly met with in infants, a little after their birth, or attacks adults in consequence of a sudden suppression of the virulent gonorrhea, or of a translation of the venereal poison in some other manner to the eyes, is called in the first case the puriform ophthalmia of infants, in the second the acute gonorrheal ophthalmia."

It does not appear that Scarpa so much as suspected the true origin of "the puriform ophthalmia in infants"—a strange oversight, for in 1750—i. e. more than half a century before, Quelmalz had plainly pointed out the cause in words that could not be mistaken. Even Beer, in his classical text-book (1813-1817) gave no heed to the great discovery of Quelmalz. Neither, as a matter of course, did it occur to Scarpa that any sort or kind of prophylaxis could be employed against this very dangerous disease.

Scarpa's treatment of "the puriform ophthalmia in infants" and "the acute gonorrheal ophthalmia" does not call for special mention here. In addition to proper regimens, it mostly consists of blisters, venesections, and astringent instillations into the conjunctival cul de sac.

The treatment of chronic ophthalmia is as follows: *Internally*—the bark, conjoined with valerian root, animal foods, and gelatinous or farinaceous broths. *Externally*—cold baths. *To the eyes*—the aromatic spirituous vapor, conducted to the eye by means of a funnel which runs from a basin of boiling water with an eighth as much of aromatic spirit.

If the chronic ophthalmia be due to a scrofulous disposition, the scrofula itself should have its proper treatment. So, too, if the trouble is due to venereal disease, the patient should be subjected to general mercurial frictions, while the eye itself is treated with the ointment of Janin, or a collyrium of muriate of mercury dissolved in mallow, or else in plantain water.

So ends our author's consideration of the subject of ophthalmia, and it will at once be noticed that he fails almost completely to distinguish one ophthalmic inflammation from another—i. e., in accordance with the anatomic situation of the affection. Thus, he says no word at all about scleritis. iritis, retinitis, choroiditis, etc. The use of a mydriatic of any sort or kind is also conspicuously absent, as is the smallest suspicion that any inflammatory affection of the eyes could either be caused or continued by an error of refraction.

Chap. VIII. Of the Nebula of the Cornea.

Scarpa first defines a nebula: "The nebula, of which I am about to treat, differs from the dense and dark spot forming the *albugo* or *leucoma*, inasmuch as it is only a recent, slight, and superficial opacity[32] of the cornea, preceded and accompanied by chronic ophthalmia, through which the iris and pupil are seen, and which does not therefore entirely take away from the patient the power of seeing,

[32] Plate II, fig. 5. a.

but only causes the surrounding objects to be seen as if covered with a veil or cloud.''

In the course of a more particular description of the disease, he holds the following language: ''In whatever part of the cornea, therefore, the nebula is situated, there is always a fasciculus of varicose veins[33] corresponding to it upon the white of the eye, more elevated and knotty than the rest of the blood vessels of the same order. And if the cornea is cloudy in several points of its circumference, there are so many distinct fasciculi of varicose veins, projecting upon the white of the eye, which exactly correspond to the different opaque points formed upon it.''

For the affection so described, and which today is known, of course, as phlyctenular keratitis, Scarpa prescribes the ointment of Janin, which, being an excellent preparation of the white precipitate of mercury, is scarcely excelled by any other treatment of today, unless indeed by the cautious administration of tuberculin and the accurate correction of refractional errors.

His tying-off, or merely dividing, the leash of nutrient vessels in the conjunctiva we need not here consider.

Chap. IX. Albugo and Leucoma.

Albugo is produced by coagulable lymph effused within the texture of the cornea, leucoma a callous cicatrix of the cornea. A recent albugo is dissipated by the very same means precisely as the violent acute ophthalmia—venesection and emollient applications, or, in a more advanced condition, by astringent applications of a gently irritating and corroborant nature. For inveterate albugo he employs either the sapphirine collyrium (tutty, aloes, calomel and fresh butter), Janin's ophthalmic ointment, or the gall of the ox, sheep, pike, barbel, etc.,[34] or else the oil of walnuts just a little rancid.

The treatments then in vogue for inveterate corneal cicatrices—i. e., leucomata—are mentioned by the writer but only for the purpose of condemning them. The chief of these expedients were ''the scraping of the laminæ of the cornea, the perforation of it, or the formation of an artificial ulcer upon a portion of the leucoma.''

Strangely enough, our author does not even mention the great discovery of Cheselden (in 1729), i. e., the artificial pupil, in connection with the treatment of corneal opacities.[35]

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[33] Plate II, fig. 5. b.

[34] The use of the gall of various animals for sundry affections of the eyes runs back farther than history.

[35] In Chap. XVI, as we shall see hereafter, he does indeed mention, but does not recommend it, for ''closure of the natural pupil.''

Chap. X. Of the Ulcer of the Cornea.

Scarpa's trusted treatment for an ulcer of the cornea is the cautious application to the ulcer of a crayon of mercury nitrate. The application is repeated on the second, third or fourth day, until the excavated spot has assumed a very light flesh-color. Then a solution of 4 grains of vitriolated zinc, in 4 ounces of plantain water and half an ounce of the mucilage of quince-seed should be employed. Toward the end of the treatment, Janin's ophthalmic ointment.

The electro-cautery was unknown to him.

Chap. XI. Of the Pterygium.

For pterygium our author recommends excision, and that alone. Having condemned the use of a curved needle and the lifting of the "pellicle" by means of a noose of thread, he describes his operation in this way: "The patient being seated for this purpose, an assistant behind him should raise the upper eyelid, with the middle and forefinger of one hand, and depress the lower one with those of the other. The operator, supposing the affected eye is the right, should place himself before the patient, either sitting or standing, as shall be most agreeable to him; then desiring the patient to turn his eye a little from the side corresponding to the base of the pterygium, with the forceps held in his left hand a little open, he should take hold of the pterygium at about a line from its apex, and press it in the form of a fold, which he should then raise and draw gently upwards towards him, until he shall perceive a small crackling, indicating the detachment of the pterygium from the fine cellular membrane which connects it to the subjacent cornea. Then, with the scissars in his right hand, he should divide the fold as close to the cornea as possible, in the direction from the apex to the base; and having carried the incision as far as the part where the cornea and sclerotica unite, should raise the fold again still higher, and with one stroke of the scissars, as concentric and close to the margin of the cornea as possible, remove the pterygium, together with a portion of the relaxed conjunctiva, which formed the base of it. This second incision should have the figure of a crescent,[36] the points of which ought to extend a few lines beyond the relaxed portion of the conjunctiva, following the curve of the eyeball."

Scarpa's day, as a matter of course, was innocent of anesthesia and asepsis.

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[36] Plate II, fig. 3.

Chap. XII. Of the Encanthis.

Scarpa described two species of encanthides—the malignant and the benign. The benign he excises, elevating first with the forceps, then making use of the curved scissors. He condemns, however, the employment of a loop of thread instead of the forceps for the purpose of lifting the growth. The malign encanthis he extirpates completely "together with all the parts contained in the cavity of the orbit." The Roentgen ray, as a matter of course, was wholly unknown to him.

Chap. XIII. Of the Hypopion.

Scarpa's treatment of hypopion is thus laid down by him: ". . . copious, general and local bleeding should immediately be had recourse to, and in the case of *chemosis*, the division of the conjunctiva; mild purgatives should be employed, blisters to the neck, bags of emollient herbs, and other auxiliaries of this kind, which have been already enumerated in treating of the first stage of the violent acute ophthalmia. This intention is known to be accomplished, by observing, that some days after this treatment, although the redness of the conjunctiva and eye-lids still continues, the lancinating pains in the eye have ceased; the heat and fever have considerably diminished; the patient's sleep and general ease are restored; that the eye can be easily moved; and lastly, that the collection of tenacious humour forming the hypopion has become stationary." Removal through a corneal opening he utterly condemns, and then continues: "I know of only one case in which the incision of the cornea, for giving issue to the matter of the hypopion may be considered, not only as useful, but even necessary, that is, where the accumulation of coagulable lymph poured into the cavity of the eye is so considerable, that from the excessive distension which it produces upon all the membranes of the eye-ball, it occasions symptoms of such magnitude as to threaten, not only the complete destruction of the organ of vision, but also the patient's life."

Chap. XIV. Of the Procidentia Iridis.

The condition in question, according to Scarpa, is occasioned by perforating wounds or contusions accompanied by rupture. For the treatment of this trouble, he rejects almost with scorn "those methods hitherto proposed for pushing back the procidentia," which can only be, he adds, "useless or dangerous." The projecting portion of the

iris he invariably destroys with the muriate of antimony or the nitrate of silver. He next proceeds to wash the eye with warm milk.

At the close of the chapter he describes a special kind of procidentia, i. e., procidentia of the tunic of the aqueous humor. "Oculists are, for the most part, of opinion, that this small pellucid tumour is formed by that subtle, elastic transparent membrane, which invests the cornea internally, and which has been described by Descemet and Demours." The treatment of this sort of procidentia is as follows: ". . . in removing by excision the small pellucid vesicle which emerges from the wound or ulcer, and in replacing the lips of the wound of the cornea in perfect contact immediately afterwards, in order that they may unite as exactly as possible. In cases of ulcer of the cornea, however, immediately after the removal of the vesicle, the ulcer ought to be touched with the argentum nitratum; and in such a manner that the eschar produced by the caustic, may resist a fresh escape of the vitreous humour, and the ulcer of the cornea at the same time be disposed to granulate and heal."

Chap. XV. Of the Cataract.

Scarpa's remarks on the treatment of cataract are interesting in the extreme, showing as they do the state of opinion regarding the great discovery of Daviel, well-nigh half a century after that discovery was made. He remarks as follows: "There are two methods of treating the cataract, the one by removing the opake crystalline, from the visual axis of the eye, by means of a needle; the other, by extracting it from the eye, by making a semicircular incision in the base of the cornea.

"It has long been disputed which of these two methods ought to have the preference; and in the warmth of discussion, the advantages of the one, and the disadvantages of the other, have been exaggerated by both parties. Observation and experience, however, the great teachers in all things, seem to have pronounced in favour of the ancient method of treating the *cataract*, or that of *depression;* not only because *depression* is more easily executed than *extraction*, and can be equally employed in every species of cataract, whether crystalline or membranous, solid or fluid; but because *depression* is attended with symptoms far less violent and dangerous than those which very frequently happen after extraction; and if from any accidental cause this operation should occasionally prove unsuccessful, it may be repeated two or three times upon the same eye without any risk; a circumstance which

extraction does not admit of, when that operation has not had the desired success.

"Influenced by these facts, I have for a considerable time laid aside the method of treating the cataract by extraction, and have applied myself entirely to the practice of depression, and I see continually great reason to be satisfied with the choice which I have made."

We should like to linger on this chapter, but recall the purpose of this abstract, which is only to enable the reader to secure a bird's eye view of the journey we have come since the time of Hammurabi, and also to take a second and more convenient starting-point, before we begin our progress in the almost bewildering labyrinth of the 19th century.

Chap. XVI. Of the Artificial Pupil.

Scarpa's observations on the artificial pupil are no less interesting and informing than those which he made on cataract. According to the cause, he distinguishes two conditions which call for the making of *pupilla artificialis*—the closure of the natural pupil in consequence of surgery for cataract, either extraction or depression, or a similar condition arising from an acute and violent inflammation of the internal membranes of the eye. He then proceeds to discuss the remedy for these conditions as follows: "Cheselden, as far as I know, was the first who ventured to propose and make a division of the iris, with the intention of forming an *artificial pupil*. He introduced a couching needle, with a cutting edge on one side only, through the sclerotic coat into the eye, at the distance of a line and a half from the cornea; then perforating the iris on the side next the external angle, and carrying the point of the needle through the anterior chamber of the aqueous humour, until it reached the side next the nose, he turned the cutting edge backwards, and retracting it, divided the iris transversely.

"It has been said that this operation has had the happiest success; but Janin has assured us, that having performed it in two instances with the greatest care, no advantage was derived from it; for after the symptoms produced by the operation had subsided, he found that in both patients the transverse opening made in the iris with the cutting edge of the needle had reunited and healed. The same thing nearly happened to Sharp, long before Janin, 'for,' says he, 'I once performed this operation with tolerable success, but a few months afterwards the very orifice I had made contracted and brought on blindness again.'

"Janin, in using Daviel's scissars for the extraction of a cataract, accidentally included the iris at the same time with the cornea, and

divided it from below upwards, on the side of the pupil, which instructed him, as he expresses it, that the perpendicular division of this membrane, on the side of the pupil, was the only effectual method of preventing the lips of the wound made in the iris from healing, and consequently of establishing an *artificial pupil*. It was this circumstance which led this oculist to invent a method of operating, and to propose as the best means of performing an artificial pupil, that of opening the cornea, as is practised in the extraction of the cataract; and afterwards of dividing the iris with the scissars from below upwards, near the pupil on the side next the nose; for in doing it on the external side, he asserts, that he had observed it to give rise to a strabismus, in consequence of the too great divergency of the optical axis." The ignorance of ophthalmologists, at the beginning of the 19th century, regarding the true nature and etiology of squint, could not have been better exhibited than by the latter portion of this sentence.

Scarpa then proceeds, because of the serious accidents which happen again and again, to condemn not only the original operation of Cheselden, but that of Janin also. He then proceeds to describe his own expedient: "All these considerations collectively, but particularly that of the weak attachment of the iris to the ciliary ligament, and consequently of the greater facility of separating the margin of the iris from the ligament to which it is united, than of lacerating the membrane itself, induced me to attempt a new method of making the artificial pupil in those cases, in which, after the extraction or depression of the cataract, the natural pupil might be too much contracted or obliterated; which method of operating consists in separating the outer edge of the iris from the ciliary ligament, for a certain extent, without previously dividing the cornea. The event answered my expectation."

In the fourth and fifth editions of his work, Scarpa admits that his procedure of *avulsio iridis* is a failure. It, however, together with the operations of Cheselden and Janin exhibit the condition of the artificial pupil operation as that procedure, or group of procedures, existed at the beginning of the 19th century.

Chap. XVII. Of the Staphyloma.

In the course of his chapter on staphyloma (which is chiefly devoted to *staphyloma corneæ*) Scarpa makes his first description of what at the present day is called "the staphyloma posticum of Scarpa." This, as we know, is the commonest cause of short-sight, is wholly acquired,

and consists of a yielding and bulging of the sclera at the posterior pole of the eye—i. e. between the optic nerve-head and the macula lutea. Its diagnosis in the living eye can only be made through the presence of a high degree of myopia and of the characteristic fundus changes which the ophthalmoscope reveals. Scarpa's two (he had no other) cases were found by him in cadavers. The ophthalmoscope (discovered in 1851) was yet far away in the future.[37]

Returning to the staphyloma of the cornea, our author declares that the objects had in view in the treatment of this condition, are three in number: "to prevent the disorganized tissues of the cornea from increasing in size, and to depress and flatten it as much as possible; and in the large inveterate staphyloma projecting beyond the eyelids, to effect such a reduction of its size, that it may re-enter and be deeply lodged within the orbit, so as to allow an artificial eye to be fixed, and thereby lessen the deformity of the countenance."

Rejecting Richter's procedure of an artificial ulcer on the cornea, he declares himself in favor of excision, "and, when the wound is healed, the application of an artificial eye."

Chap. XVIII. Of the Dropsy of the Eye.

For this affection, which is called today "buphthalmos," Scarpa recommends, in moderate cases, a seton in the neck. "But as soon as the eyeball begins to protrude from the orbit," he performs "an operation which consists in evacuating the superabundant humours of the eye by means of an incision, and thereby obliging its membranes, in consequence of a mild inflammation and suppuration of the internal part of the eye, to contract themselves, and retire to the bottom of the orbit. Condemning the simple paracentesis of Nuck, together with Woolhouse's addition of a six-fold rotation of the canula within the eye, before its removal, and Platner's injections through the canula of tepid water, as well as Mauchart's attempt to preserve a permanent aperture by means of a tent of lint, he declares that "the perfect cure of this disease can only be obtained by emptying the eye of its humours, and at the same time exciting in its internal membranes a certain degree of inflammation and suppuration." He then proceeds to recommend the same procedure precisely as that advised by him for staphyloma of the cornea, in Chapter XVII.

[37] The posterior staphyloma of Scarpa is to be distinguished from the posterior scleral protuberance of von Ammon—which lies not quite at the posterior pole of the eye, but a little below it, and which, moreover, is never acquired, but congenital.

Chap. XIX. Of the Amaurosis and of the Hemeralopia.

To show the confusion which prevailed at the beginning of the 19th century concerning the various deeper affections of the eyes, I quote hereunder from Scarpa's definitions, distinctions, etiology, etc., of the amaurosis, at considerable length. The time and space will not be thrown away. "The amaurosis is *perfect or imperfect, inveterate or recent, continual or periodical.* The *perfect inveterate amaurosis,* with organic injury of the substance constituting the immediate organ of vision, is a disease absolutely incurable. The *imperfect recent amaurosis,* particularly that which is *periodical,* generally admits of a cure, since it is most frequently connected with a disordered state of the stomach and primæ viæ, or is dependent on causes, which though they affect the immediate organ of vision, may be removed without leaving any trace of disorganization, either in the optic nerve or retina.

"In general, those cases of amaurosis may be regarded as incurable which have existed for several years, in persons advanced in age, and whose sight has been weak from their youth; those which have been slowly formed, at first with a morbid increase of sensibility in the immediate organ of vision, and afterwards with a gradual diminution of perception in this organ to complete blindness; those in which the pupil is immoveable, without being much dilated, but where it has lost its circular figure, or when it is so much dilated as to appear as if the iris were wanting, having also an unequal or fringe-like margin; in which the bottom of the eye, independently of the opacity of the crystalline lens, has an unusual paleness, similar to horn, sometimes inclining to green,[38] reflected from the retina as if from a mirrour;[39] which are accompanied with pain of the whole head, and with a constant sense of tension in the eyeball; which have been preceded by great and protracted incitement of the whole nervous system, and afterwards by general debility and languor of the whole constitution, as after the long abuse of spiritous liquors, manustupration, or premature venery; those which have been proceeded or accompanied by

[38] It is just a little strange that Scarpa nowhere in his volume mentions the word, "glaucoma." The term (without, of course, its modern meaning of pathologic hypertension in the eye) was used by Galen, Celsus and even Hippocrates.

[39] The retina of a sound eye is transparent, and, therefore, in any degree of dilation of the pupil, the bottom of the eye is of a deep black color. [The real reason for the darkness of the pupil was announced by Kussmaul in 1845. But of this hereafter.] This unusual pallor then which accompanies the amaurosis indicates that a considerable change has taken place in the substance of the optic nerve forming the retina, which, according to all appearance, is become thickened, and rendered permanently incapable of transmitting the impressions of light. This sign, therefore, is one of the most unfavorable.—Scarpa.

attacks of epilepsy, or by frequent and violent hemicrania;[40] which have come on in consequence of violent and obstinate internal ophthalmia, at first with an increased, but afterwards diminished sensibility of the retina, and slowness of motion in the pupil; which, besides being inveterate, are the consequence of blows upon the head; which have been occasioned by direct blows upon the eyeball; which have appeared after violent contusion and laceration of the *supraorbital* nerve, whether this has taken place immediately after the blow, or some weeks after the healing of the wound of the supercilium; which have been occasioned by extraneous bodies penetrating the eyeball, as leaden shot, &c.; those which are derived from the confirmed lues venerea, in which the presence of one or more exostoses upon the forehead, upon the sides of the nose, or upon the maxillary bone, lead to the suspicion that there may be also similar exostoses within the orbit: lastly, those which are conjoined with a manifest change of figure and dimension of the whole eyeball, as when it is of a long oval figure, or of a preternatural bulk or smallness. . . .

"On the contrary, those cases of *recent imperfect amaurosis*, most frequently at least, if not always, admit of a cure, which, although the patient be almost, or even completely deprived of sight, have not been produced by any of those causes which are capable of contusing, or destroying, the organic texture of the optic nerve or retina; in which the immediate organ of vision preserves some, though little, sensibility to the light, whether in the direction of the axis of vision or laterally; those cases of sudden or recent amaurosis, in which, although the pupil is preternaturally dilated, it is not excessively so, and is regular in its circumference; behind which the bottom of the eye is of a deep black colour, as in a natural state; which have not been preceded or accompanied by violent and continual pain in the head and eye-brow, nor by a sense of constriction in the eye-ball; which have originated from violent anger, excessive grief or terror; those which have succeeded an excessive fullness and crudity of the stomach, plethora either general or confined to the head, the suppression of accustomed sanguineous discharges from the nose, uterus or hæmorrhoids; those occasioned by an evident metastasis of variolous, rheumatic, herpetic, or gouty matter; which are the consequence of profuse loss of blood; which are to

[40] Scarpa, of course, knew nothing at all about the connection of eye diseases and headaches with empyema of the nasal accessory sinuses—a connection the discovery of which is still so recent that the great majority of doctors are yet in considerable ignorance concerning it. Just why the relation of the various sinusitides to paresis, or paralysis, of the various ocular muscles, to retro-bulbar neuritis, etc., should have been deferred so long (the maxillary antrum was discovered *circa* 1650) is one of the mysteries of medicine.

be referred to a nervous debility not inveterate, in persons who are young, and which in consequence are yet susceptible of being remedied; those produced by convulsions and violent efforts during a laborious parturition; those which accompany the course or decline of acute or intermittent fevers; and those, lastly, which are *periodical*, or which come on and disappear at intervals, every day, every three days, every month, or at a certain season of the year.''[41]

For the ''cure'' of the ''imperfect amaurosis'' our author recommends at first ''emetics and internal resolvents.'' This he follows by roborant treatment, directed especially to the stomach and the nervous system—i. e. cinchona and valerian root. The patient should live on succulent food and cooling broths, ''take a moderate quantity of wine and use gentle exercise in a salubrious air.'' For a local application, the vapour of aqua ammoniæ puræ is the best.

For ''the imperfect periodical amaurosis'' he first condemns the early use of any preparation of cinchona (the disease being in nowise owing to malaria) and proceeds to recommend the treatment above laid down for the imperfect amaurosis in general, in which the powder of cinchona is employed comparatively late.

A rather circumstantial footnote at the close of the amaurosis portion of this chapter, is especially interesting and instructive, because of the light which it sheds on the attitude of Scarpa (therefore of ophthalmologists in general) toward the condition known today as asthenopia from errors of refraction: ''It occasionally happens that patients, in these cases, cannot look at a very near object, with one or both the eyes, without experiencing fatigue and pain in one or both of them, while they feel no inconvenience from looking at an object at a certain distance. And when the difficulty which they find in looking at a near object is confined to one eye, it is accompanied with strabismus and double sight. This depends upon a debilitated state of the muscles of the eye, in consequence of which the patient cannot conveniently accommodate the eye-ball to very near objects, or maintain it for a length of time in this position; and when the debility is confined to the muscles of one eye, this being unable to concur in the actions of the other, strabismus and double vision are the necessary

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[41] The belief in a mystic relationship of numbers, which we saw so strongly developed in old Hippocrates, and which that master, in turn, had got from the early philosopher, Pythagoras, died hard in the 19th century. Thus, e. g., Scarpa, commenting on the results of ''emetics and internal resolvents'' for ''the imperfect amaurosis,'' declares: ''Sometimes on the same day on which he has taken the emetic he begins to distinguish the surrounding objects; at other times this advantage is not obtained till the 5th, the 7th, or 10th day.'' We can easily imagine the reverent ophthalmologists of 1801 carefully storing away these figures in their memory.

consequences. This inconvenience is also remedied by the general and local corroborants before mentioned, and by avoiding to strain the muscles of the eyes. And if the debility be confined to one eye only, and occasion the strabismus, it will be advantageous to keep the affected eye covered for some time."

It remained for Thomas Young to discover astigmatism, for Airy to rectify it, for Böhm to learn that *hebetudo visus* may be truly relieved "by the insane practice of wearing the spectacles of one's grandfather," for Hermann von Helmholtz to invent the "Augenspiegel," for Jaeger to show the value of that instrument for the objective determination of errors of refraction, and then for Donders and Helmholtz so to harvest the field in which the wondrous crop had then been sown, that nothing remains for aftercomers to do, except, like women and children, to pick up here and there "the leavings of the mighty."

Scarpa passes, then, to the consideration of *hemeralopia*, by which he means (as we of today do not) "nocturnal blindness."[42] This disease, he says, is "sympathetic of disorders of the stomach," and is best to be cured, he continues, by the very same treatment as that applied in the imperfect amaurosis—emetics, purges, powdered cinchona and valerian root, attention to diet and exercise, and, finally, vaporization locally with "the aqua ammoniæ puræ."

Chap. XX. Of a Calculous Concretion of the Internal Part of the Eye.

In this, the final chapter of the volume, Scarpa reports a case in which the eye of a woman was "almost entirely transformed into a stony substance." The case has no importance in this summary, and hence is best omitted.

Now, in a retrospect of Scarpa's volume, we of the 20th century are struck most forcibly with the following important differences from the ophthalmology of today: (1) Scarpa had no knowledge at all of the actual nature of dacryocystitis; (2) no means whatever of preventing ophthalmia neonatorum; (3) no knowledge at all of the adequate treatment of cross-eye, plus a very mistaken notion of the etiology of the disease; (4) no confidence whatever in the extraction method of operating for senile cataract; (5) nothing but absolute ignorance on the subject of sympathetic ophthalmia; (6) no knowledge whatever about the visual field; (7) a trifling perception of the nature and results of eye-strain, the use of spectacles, the rôle of errors of refraction in the production of apparently independent diseases—styes,

[42] See, in this *Encyclopedia*, **Day-Blindness** and **Hemeralopia**.

detachment of the retina, etc.; (8) not even so much as an inkling, of course, about asepsis and anesthesia; (9) no knowledge at all of the various eye inflammations as they are classified today; i. e., upon an anatomic basis, keratitis, iritis, retinitis, choroiditis, et cetera.[43]

We are now, I think, in a fairly good position to attack the ophthalmologic history of the 19th century. In order, however, to divide the forces of the enemy, and so to mass our own assaulting column well, we will first consider (1) Anatomy and Physiology; then (2) Diagnosis and Pathology (inclusive of Symptomatology); next (3) Prophylaxis and Treatment (including the Treatment of Errors of Refraction); finally, (4) Surgery.

Anatomy and Physiology.

Anatomy.—The macroscopic anatomy of the eye had, as a matter of course, been thoroughly developed before the beginning of the 19th century. The great improvements in the microscope,[44] however, which were made in the second, third, and even fourth and fifth decades of the 19th century, gave to the study of the microscopic structure of the eye a new and enormous impulse. Even before these great improvements, however, a number of preliminary discoveries had been made.

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[43] Nearly all these various affections of the eye were covered, at the outset of the 19th century, by the blanket-expression, *ophthalmia.* Sometimes, to be sure, a distinction was made between ophthalmia *externa* and *interna.*

[44] Just when or by whom the microscope was invented is unknown. The magnifying effect of a simple (not compound) lens was noted, as we have said before, by Roger Bacon. The microscope (or compound system of lenses) was invented, as all agree, at some time between 1590 and 1609, and by one or the other of certain spectacle-makers of Middleburg, Holland—Hans Janssen, Zacharias Janssen (his son), and Hans Lippershey. The earliest work on the microscope was that of Dr. Hook, entitled "*Micrographia,*" which appeared in 1665. Hook was also the first to suggest the importance of a wide aperture in the instrument. The first to apply the microscope in ophthalmology was, as we have seen, Leeuwenhoek (1632-1723), who discovered the rods of the retina, the fibres of the lens and of the cornea, as well as the epithelial layer of the latter membrane. Leeuwenhoek, however, did not really use the microscope, but only a series of simple lenses, one at a time. Lieberkühn also, in 1738, made all his discoveries (including the histology of the mucous membrane of the alimentary canal) by means of simple lenses. Lieberkühn, too, invented the reflector. The method of measuring the magnifying power of a microscope in diameters was introduced by Benjamin Martin, who also produced an achromatic objective in 1759 and a micrometer stage not long afterward. A host of changes and a number of permanent improvements were introduced in the instrument from the middle to the close of the 18th century. In the 19th century decades mentioned above, an extremely important suggestion was made for the improvement of the microscope, by Sir David Brewster—i. e., that the lenses of this instrument should be constructed of materials possessed of a high degree of refractivity. Amici introduced, in 1815, the immersion system, and Frauenhofer, of Munich, succeeded in constructing object-glasses composed of just two pieces, which, though placed in contact with each other, were not cemented together, and which, as a whole, were extremely achromatic.

Thus, Soemmering in 1801 described the macula lutea, which long was known as the yellow spot of Soemmering and the *fovea centralis,* which, at first, was generally called "Soemmering's foramen."

Jacob, of Dublin, in 1819, described the retinal layer of rods and cones, the structure which bears his name today. Before his time the retina was regarded as being composed of just two layers only—"the medullary expansion of the nerve" and "the membranous, or vascular, layer." The latter was situated next to the vitreous humor.

Schneider, in 1827, showed the existence and the situation of the *ora serrata.* Schlemm, in 1830, discovered the circumcorneal canal which bears his name today, and which later was destined to have so great a bearing on the pathology of glaucoma. He also discovered the nerves of the cornea. In 1836, Valentine discovered and described the pavement epithelium of the conjunctiva and the cornea. He divided the retina into four layers, and demonstrated clearly the muscular fibres of the iris. Eble, in 1838, showed the papillary bodies of the conjunctiva.

Hannover, in 1840, brought to our knowledge two more layers of the retina, the granular and the fibrillar.

Pappenheim, in 1842, almost created our knowledge of both the microscopic and the macroscopic structure of the vitreous.

Sir William Bowman discovered and first described, in 1849, the "anterior elastic lamina" of the cornea, as well as "the corneal interspaces"—structures better known today as "Bowman's membrane" and "Bowman's tubes."

Bowman, also, in 1850, first described the retinal membrana limitans.

Later workers in the microscopic field were: Krause, Kölliker, Sappey, Richet, Cadiat (upon the lens in 1876), Ramon y Cajal (upon the retina in 1892). The latter investigator, using the Golgi stain, produced the list of retinal layers which is still most commonly accepted.

Meanwhile, the macroscopic anatomy of the eye, a subject which had not been wholly exhausted by the workers of the 18th and some of the preceding centuries, had also been developed, though not (for obvious reasons) with the same rapidity.

One of the earliest of the macroscopic structures to be investigated fully in this century, was the ocular fibrous envelope, or ocular capsule. This fibrous covering of the eye was indeed known to the ancients, but only very vaguely. In 1802, however, a Parisian anatomist, Jacques René Ténon, described the structure in question with more particularity. His excellent contribution, all the same, was wholly ignored till the invention of the strabismus operation in 1839 and 1840.

Then Bonnet, a Lionese surgeon, re-discovered "the fibrous capsule of the eye," and described it very much better than his careful countryman, Ténon, had done. His very exact description of the structure, in fact did much to advance the operation for strabismus. "In order to rise to a truly scientific conception of the strabismus operation," he says, in his "*Traité des Sections Tendineuses et Musculaire,*" etc., "one has to determine under what conditions the muscles to be tenotomized at their insertion in the sclera keep or lose their influence upon the movements of the eye. Otherwise one cannot know what one has to do, in case the squint continues subsequent to the tenotomy, and how a conversion into the exactly opposite form of squint is to be prevented." Bonnet showed in this as well as in other writings, that the recurrence of a squint subsequent to operation is owing to a union of the muscle to the capsule and of this to the ball of the eye. He also pointed out the necessity, in such cases, of a freer division of the fibres of the ocular capsule, especially in the case of grown persons. He showed, further, that both the oblique muscles tend to turn the eyeball outward, and that, in outward squint, it is usually needful to tenotomize the inferior oblique in addition to the rectus externus.

His description of the ocular capsule was, as I have said, better than any that had preceded. This capsule, to use his very expression, is formed of a fibrous membrane, in which the eye is held like an acorn in its cup. The capsule is, therefore, concave forwards, is united behind to the optic nerve where the structure enters the eyeball, and, coming forwards, encloses the posterior two-thirds of the ball. It does not, however, cling to the eye closely. It terminates in front by a number of fibrous expansions, of which the most distinct pass to the cartilages of the lids, so that these constitute the actual termination of the capsule. "All the muscles of the eye perforate the capsule in order to reach the sclera; they therefore consist of two portions—one outside, one inside, the capsule. Both parts are inclosed in sheaths which proceed from the capsule; the sheath for the intracapsular portion of each tendon passes to the sclera, to which it is united. The capsule, therefore, ends anteriorly in two leaves; the one goes to the eyeball and follows the subconjunctival fascia and the sheaths of the intracapsular parts of the recti muscles; the other betakes itself to the lid-cartilages. The forward-opening angle, which the two leaves form, is the place where the scleral conjunctiva is reflected upon the lids. The sheaths of the outer and the inner recti muscles send out strong processes to the margins of the orbit."

Between the time of Ténon's description and that of his great successor, Bonnet, (an interval of 39 years) Malgaigne, Baudens, Poyer

and Guérin, each contributed something to our knowledge of the structure in question. Then came Joseph O'Ferral, a celebrated Irish surgeon and re-inventor of the enucleation of the eyeball, who in 1841 (*Dublin Jour. of Med. Science*, p. 329) described the fibrous capsule of the eye still more specifically and clearly than Bonnet himself had done. Since then but little has been contributed to our knowledge of this structure.

We need to mention that Adolf Kussmaul, while yet an undergraduate at Heidelberg (in 1805) published an original contribution, entitled "Die Farben-Erscheinungen im Grunde des Menschlichen Auges," in which he was first to show that the retina of man and other mammals is, in the fresh condition, absolutely transparent. The importance of this discovery, of course, was much more obvious after the discovery of the ophthalmoscope (1851).

Next, Jules Germain Cloquet, in his widely celebrated "*Anatomie de l'Homme ou Description,*" etc. (Paris, 1821-1831, 5 vols.) contributed the first description of the hyaloidean canal, now known almost universally as the canal of Cloquet. The description (translated, of course) runs as follows: "At the level of the entrance of the optic nerve, the hyaloid membrane is reflected on itself, to form a cylindroid canal which traverses directly the vitreous from behind forward, and encloses the nutrient artery of the crystalline lens. This canal, which I believe myself to be the first to make known, and which I have named hyaloidean, can be perceived only when the membrane has been rendered slightly opaque, by means of procedures which I have described elsewhere."

Though the canal itself had never been described before, yet, in 1812, Francisco Martegiani had described the slight dimple, or cone-shaped depression in the vitreous body, at the site of the optic papilla, which depression, therefore, in his honor, is called today the area Martegiani. Martegiani's book, containing this description, was first published in 1814.

The next important discovery in the macroscopic (if so we may call it in this connection) anatomy of the eye was that of the ciliary muscle, made first in 1846 by Brücke, and independently in 1847 by Sir William Bowman. Brücke, however, recognized only meridional fibres, Bowman both the meridional and the radial. Brücke called the muscle *M. tensor chorioidea*; Bowman, however, proposed the designation, *musculus ciliaris*. Müller, in 1857, described the muscle with greater particularity than either Brücke or Bowman had done.

As a matter of course, the macroscopic anatomy of the eye has made but little progress in the last three-quarters of a century—the

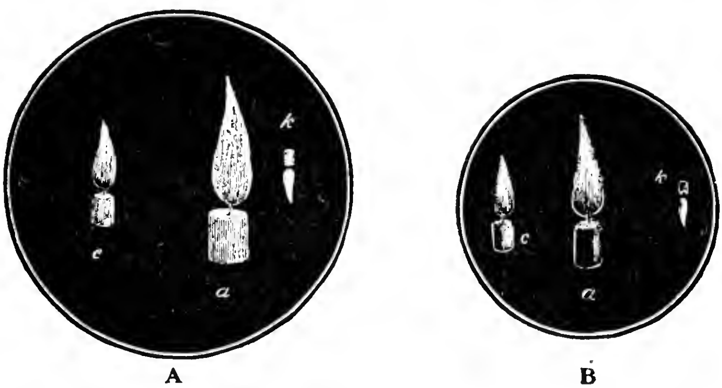
subject was, in its very nature, inclined to early exhaustion. Something additional, to be sure, was learned about the macroscopic features of the fundus, as soon as the "Augenspiegel" had been described by Helmholtz.

Physiology.—Thomas Young, of London, at the close of the 18th century (in 1799) in his paper, "Sound and Light," had revised the undulatory theory of light, which had already been propounded by Christian Huygens in 1678, and placed that theory on a permanent foundation. And he did this even better in a later work, a book, "*On the Theory of Light and Colors*" (London, 1802). It now remained for the distinguished genius at the very beginning of the century to clarify our knowledge of the act of accommodation—that physiologic process whereby light, whatever its nature may be, is rendered available for use by the retina and the centers for vision in the brain. He showed, that is to say, that the power to bring to a retinal focus rays of light emitted from points that are somewhat near to the eye, can only be secured by the assumption of an increased convexity of surface on the part of the lens, a closer approximation of that structure to the spherical form. Young, however (and most unfortunately), adopted the view that the lens itself was muscular structure, and that the changes in shape which the lens must undergo in the course of an adjustment to light which comes from nearer or farther distances, could only be produced by contractions and relaxations in the very substance of the lens. This was a view which long before the time of Young had been declared emphatically—i. e., by Leeuwenhoeck and even by Descartes—and which Home and Ramsden as early as 1794 (*Philos. Transac.*, p. 21) had completely overthrown. And even the view that the power of accommodation depends on changes in the form of the crystalline lens, had also been conceived before Young's time—i. e., by Porterfield, who, about the middle of the 18th century, had noted the absence of accommodation absolutely in the eyes of those who had undergone a cataract operation: still, to Young is due the credit of securing, at least to a large extent, this, the now proved theory, of the essential nature of accommodation—i. e., that the process in question depends on certain alterations in the form of the lens.

Not all at once, however, did the doctrine make its way. Thus, as summarized by Pansier (Histoire de l'Ophtalmologie, in *Encyclopedie française d'Ophtalmologie*, I, p. 58) "The principal theories [of accommodation] which were held in the first half of the 19th century, are as follows: (1) The accommodation is a reflex act which pupillary changes are sufficient to explain (Pouillet); (2) The accommodation

is produced by a change in the curvature of the cornea (Fries, Vallée, Pappenheim); (3) The accommodation is the result of the pressure exercised by the recti or obliqui muscles, which bring about an elongation or abbreviation of the optic axis (Meckel, Henle, Listing, Maunoir, Arlt, J. Guérin, Petrequin); (4) The accommodation is produced by a displacement of the lens (Jacobson, Müller, Szokalsky, Ruete, Hannover); (5) Finally, the ultimate theory was constructed by Purkinje, Graefe, Smith, Stellwag von Carrion, a theory which explains the accommodation by a change in the form of the crystalline."

From the making of the ultimate theory (if ultimate it be) Porter-



Purkinje Images.

field and Young are wrongfully excluded by Pansier, but, otherwise, his summary would seem to be correct.

The next great step in our knowledge of the accommodation was taken by Johannes Evangelista Purkinje, who, in his "*Beobachtungen und Versuche zur Physiologie der Sinne*" (Berlin, 1823-26, 2 vols.) announced the important discovery of what are known today as "the Purkinje-Sanson images."[45] These images are three in number: the first and second, erect, are reflections from the anterior surfaces of cornea and lens respectively, the third, however, inverted, from the (forward) concave posterior lenticular surface. The first of these images was very well known to the ancients, who, however, believed that it had its origin either on or in the lens, instead of on the cornea. Scheiner was the first to indicate its true origin. The value of these images in showing beyond a doubt the fact and nature of the formal

[45] These images were all discovered by Purkinje. Inasmuch, however, as Sanson was the first to apply them all diagnostically, they are almost always called, today, "the Purkinje-Sanson images."

changes in the lens which result from the adjustment of the eye to light from different distances, simply and literally "cannot be over-estimated."

Max Langenbeck, however, as well as Cramer and von Helmholtz, about the middle of the century (that time of unparalleled achievement in our art) confirmed with still further experiments the findings of Purkinje. Helmholtz, in fact, by means of a so-called "phaeoscope" was able to determine the actual radius of curvature of the anterior surface of the lens both in a state of maximum accommodation (when it was found to be 6mm.) and also in a state of rest (when it was found to be fully 10 mm.). Heine, later, discovered that, in the act of accommodation, the lens dropped slightly downwards.

Helmholtz, in addition, invented his valuable ophthalmometer, whereby he determined with marvelous accuracy "the position and curvature of the surfaces which separate the refracting media of the eye, as well as their changes during the act of accommodation. The changes in the anterior surface of the lens alone, according to the findings of his ophthalmometer, were nearly sufficient to account for the total accommodative power.

The problem of accommodation was, of course, still further cleared up by the finding of the muscle of accommodation by Sir William Bowman in 1847.

We may, in closing, say that the problem of accommodation is not yet wholly solved. The numerous theories, however, which are prevalent today regarding the nature of the process, can all be found in the various non-historic portions of this *Encyclopedia*—especially in Vol. I, pp. 48-53 (Helmholtz's, Cramer's, Carmona y Valle's, Grossmann's, Müller's, and Tscherning's), also beneath the captions, **Refraction and accommodation** and **Physiological optics.**

The movements of the eye as a whole, were studied by Müller (1825) and by Volkmann a little later. The conclusions of both these men, however, were very incorrect. Listing, in 1857, achieved much better results, though he muddled many matters, and Volkmann's considerably later researches determined the cardinal points correctly. The efforts of von Helmholtz, strange to say, did little except to obscure the already darkened subject, while even von Graefe was not much more successful. To Maddox is due great credit for light on this mountainous and deep-caved territory, while George T. Stevens, of New York, is its great, wide-ranging explorer. Stevens, in fact, it was who named its peaks and valleys, measured its more important distances, and entered its most profound recesses. Claud Worth, of London, too, has done much yeoman service in the Africa of ophthal-

mology, as well as has Savage, of Nashville.[46] The subject of motility, however, is so very, very recent, that most of its history is, of necessity, either expressed or implied in the latest and most scientific exposition of that portion of our art. See, herein, **Muscles, Ocular.**

The "shutter" of the eye, the iris, was studied by Kölliker, Iwanoff, Grunhagen, Schwalbe, Rochon-Duvignaud, and others, each adding a little to our stock of knowledge about this structure. It will be remembered that the first to notice the light-reflex of the iris was the old Arabian, Ar-rhazi, or Rhazes, who flourished in the 9th century of this era.

The art and science of *perimetry* was largely a 19th century development. It will be recalled that the ancients had given a little attention of a vague and desultory character to defects in the visual field, while the Frenchman, Mariotte, in 1666, had discovered the normal blind spot. Thomas Willis, next (in 1676) for the very first time in history referred defects in the visual field to pathologic alterations in the retina.[47] In 1708, moreover, Boerhaave, a Dutchman (the same who was later to play so great a part in introducing into every portion of the world the new and proper doctrine concerning the nature and situation of a cataract) had written a very little on scotomata, both positive and negative. And that was the whole extent of the science and art of perimetry until the time of Thomas Young. This great investigator, then, in his chief ophthalmic work, entitled "The Mechanism of the Eye," (read before the Royal Society in 1800, and published in the *Philosophical Transactions* in 1801 [48]), developed the science of perimetry almost, though not quite, *ab initio*, and to a very high degree.

The first description of concentric contractions was furnished by Joseph Beer, of Vienna, in 1817.

The actual value of perimetry as a means of ophthalmic and general diagnosis was pointed out and emphasized by Albrecht von Graefe in 1856.

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[46] I trust it may not be out of place to acknowledge here the debt of gratitude we owe to Savage for the degree to which he has clarified and sharpened the ideas of the ophthalmologic world with respect to matters of motility. His great success in this regard is largely owing to his literary style, of which the following sentence may stand as a fair example: "Duction is not volitional but fusional, and is under the control of the guiding sensation, whose dominion is limited, and whose throne is the central point of the macula." Clear, rhythmical, pictorial and compact, it is difficult to see how scientific style could ever be made better.

[47] A discovery which was only possible, of course, after the final re-establishment by Kepler (in 1604) of the retina as the essential visual apparatus. Before that date the lens was supposed to be the percipient organ of the eye, except by a very few persons, for example Leonardi da Vinci.

[48] The date of Scarpa's book. Scarpa, it will be remembered, did not so much as mention the visual field.

Next came Foerster with the first perimeter, in 1868.

Here is what he says about it, and the principles on which it is based, at the beginning of his article, "Mensurations du Champ Visuel Monoculaire, dans Diverses Maladies de la Rétine et du Nerf Optique," which appeared in *Annales d'Oculistique*," Tome LIX, Jan. and Feb., 1868: "One may imagine the visual field as being a hollow hemisphere, placed vis-à-vis with the eye, and the center of which corresponds with the optical center of the ocular globe. The line of vision ends at the pole of the hollow sphere, and this pole, the optical center and the fovea centralis of the retina are situated on the same straight line.

"The hollow sphere and the retina are hardly concentric; they have the same meridians and each point of the retina has, on the hollow sphere, a corresponding point, which is determinable by degrees of longitude and of latitude. This hollow hemisphere can be replaced by a half circle, traversed in its middle by an axis round which it executes movements of rotation. If the semi-circle be made to perform a revolution of 180°, it describes the surface of a hemisphere; if this rotation is increased to 360°, each point of the semi-circle has traced in its progress a circle of latitude, and each position of the circle represents at the same time a meridian. If this semi-circle offers, at one of its points, a movable object, this point can be transported on each point of the hollow hemisphere, and its position determined by degrees of latitude and longitude.

"I have made, by the aid of an instrument constructed on this princple, my researches on the visual fields. Here is how I went about it: The radius of the arc, composed of blackened brass wire, has a length of 12 inches and each dial is divided into 90°. The division commences near the axis, and each end of the arm marks the 90th degree. The movable object consists of a bit of white paper, a fourth inch square, on a black foil. One marks the points where the object appears and those where it disappears.

"In order to obtain drawings which, at a glance, enable the beholder to recognize the configurations of the visual fields, the result of the measurings is traced on a round map, of which the center corresponds to the axis of the arc. Twenty radii drawn in the round map represent these different positions of the arc. Each radius is divided into 70 parts which are equal to 70 degrees of the arc. The 70 degrees suffice to determine the entire visual field, in the majority of directions, because *the diametral extent of the visual field*—as it resulted from my first researches—*seldom exceeds 140 to 150 degrees.* For, I have found that, if the visual line is directed straight forward, *the extent of the*

visual field on the inner side of the point of fixation does not exceed 50 to 55°, but reaches to 85° on the outer side. Consequently, *the spot of Mariotte is situated nearer the center of the visual field than the point of fixation,* which lies 15° on the inner side of the spot of Mariotte. The filaments of the optic nerve, radiating on all sides, from the papilla of this nerve, to which the spot of Mariotte corresponds, one might conjecture that this spot played a rôle in certain defects of the visual field. It was for this reason that, in my further researches, I chose the point of fixation at 15° to the inner side of the axis of the arc. The spot of Mariotte falls then upon this axis, and the positions of the arc correspond rather to the direction of the filaments of the optic nerve than to the physical meridians of the globe of the eye." [The rest of the article is occupied with descriptions and illustrations of the monocular fields in (1) health, (2) optic atrophy, (3) glaucoma, chronic and acute, (4) amblyopia consequent upon cerebral apoplexy, and (5) the common binocular field in its relation to the two monocular fields.]

Since Foerster's fine (and earliest) instrument, a number of others have been invented—notably Dana's, MacHardy's, Skeel's, and Smith's—but for these the reader is referred to the non-historic portions of this *Encyclopedia* (see especially **Perimetry**).

Another discovery, or invention, of the 19th century in ophthalmic physiology (as well as, of course, in pathology and diagnosis) was that of the value and use of photometry in ophthalmology. There had been commercial photometry and photometers before this century, but, for the first ophthalmo-diagnostic photometer (as well as the principles involved in its use) our thanks are in fact owing to the same Richard Foerster, ophthalmologist of Breslau, Germany, who invented the first perimeter.

Foerster described his instrument and expounded the principles of its use in ophthalmology in an inaugural dissertation, presented on the occasion of his habilitation as privatdocent in ophthalmology at the University of Breslau, in 1859, the title being "Ueber Hemeralopie und die Anwendung eines Photometers in Gebiete der Ophthalmologie." The beginning of the dissertation (which runs as a whole to 48 pp.) will make sufficiently clear the nature of the instrument and the principles of its application:

"Introduction.

"The activity of the visual sense has two qualitatively different relations: it renders possible *first* the contemplation of superficial extent (of space, space-sense: Weber) and *secondly* that of light (colors).

"There are, in consequence, two limitations which bound the visual sense in its activity, namely: a certain smallness of the visual angle and a certain weakness of the illumination.

"Visual angle and illumination are, so to speak, the two factors from which results the sharpness of the impressions which we receive through the eyes. The smaller the one is, the larger must be the other, if a perception is still to be the result—they complement each other mutually.

"Instead of 'illumination' we could more correctly say 'contrast,' for in order that an object may be perceived, an excellent illumination is not so much the necessary prerequisite, as a certain contrast, in which the object stands to its surroundings with respect to its brightness and color. An object may, under the same, or even a better, illumination, remain invisible to us, or at least appear very indistinct, so soon as it fails to contrast properly with its environment. I recall at this point the stars, which are present under just as bright an illumination in the sky of day as in that of night; in the day, however, the contrast is wanting.

"A spirit flame before a brightly illuminated white wall is not seen. Here too is a failure of contrast (not failure of brightness) by which the perception is hindered. Our daily lives bring us many examples of this principle, that the visual angle and contrast complement each other mutually. A person who reads in the twilight is compelled to hold the print closer to his eyes. Myopic persons therefore can read in a very low illumination. The difficulty in recognizing the letters which results from the low illumination is, in this case, lessened by the reader's enlargement of the visual angle of the letters; the illumination, of course, remaining unchanged when the book is approached toward the eye. The weaker, however, the illumination, the less is the contrast between the black letter and the white paper. When, however, a person is necessitated by his accommodation-apparatus to hold the book at a distance from his eyes, so that, in this way, the visual angles of the letters are made relatively small, then he will require a brighter illumination, i. e., a stronger contrast. Presbyopic persons are in this case.

"If, then, the *smallest* visual angle under which our eye still perceives an object plainly, is smaller or larger according to the contrast of the object with its surroundings, then it is clear that all the measurements of the smallest visual angle, which take no account of the strength of illumination under which the measurements are made, suffer from a certain defect. In this way, too, occur certain divergencies in results.

"It is, then, not really sufficient, to hold in front of a diseased eye that is going to be examined, test-letters of different and definite sizes, and to evaluate its capacity by its power to recognize the smallest; it must also be seen to that the contrast is a definite one.

"Accordingly, two ways exist whereby the visual power may be investigated. Either we test the space-sense of the retina by holding before it under a relatively good and always equal illumination objects of a different visual angle, or we measure its sensitiveness for light (light-sense), by bringing in front of it objects which are always of the same size under an illumination which may be increased or diminished at will.

"To furnish a contribution to the latter method is the object of the following lines:

"Photometric Apparatus.

"Unfortunately, the science of physics has not yet been presented with a photometer whereby we may produce at will a graduated illumination with certainty and quickness, as for example we read off the degree of heat on a thermometer scale. In photometric determinations we are always ultimately under the necessity of appraising with our eye—therefore quite subjectively—the equality of two magnitudes. I have attempted, by the apparatus to be described hereafter, to avoid this subjective determination, to assume any desired light-source to be equal to unity, and, by an increase of its outward extension to produce an illumination which could be expressed numerically, under which then the objects would be exposed. The apparatus is therefore not so well adapted for the measure of given quantities of light [49] as for the production of any desired and *measurable* illumination. Whoever, on this account, shall take offense at the name "photometer," may invent something better: [50] I will gladly give my own term up.

"In the investigation of the visual power, it is far less requisite to have a photometer for every possible degree of light, even the stronger ones, as for a gradual measurement of proportionately *slight* light intensities; just as, in the testing of the space-sense, it is desirable to recognize the *smallest* visual angle, under which an eye still perceives distinctly, for which reason we employ for the purpose letters—that is, objects relatively small. It will therefore suffice for our purpose, if

[49] As for example, the photometer of Count Rumford had been.

[50] That would not be difficult, for Foerster's instrument, strictly speaking, was not a light-measurer at all, but a light-*sense* measurer. It was therefore, in truth, the first of its kind in history.

we construct such a photometric apparatus as includes only the lower end of a general light-scale. It might appear to be simplest to employ for this purpose a light-source of definite, and, so far as possible, of uniform intensity, and, by approximation toward the object or removal from it, to secure the varied illumination. Inasmuch as the strength of the illumination diminishes as the squares of the distance increase, the illumination of the object at any given moment would be easy to compute. But such apparatuses are not very compendious, because all diffuse light which can fall from other points upon the object, must be excluded, consequently the light must travel in black rooms, and because, if one would operate at small distances, a sufficiently weak and yet approximately constant light-source would be hard to provide. Because by still other methods the *altered intensity* of a light-source is still mere troublesome to measure, I have decided to have this of *uniform* intensity, but of varied magnitude, and so have made use of the following photometric contrivance.

"A box, parallelopipedonic in form, closed on all sides, and blackened within, of about 36 inches in length, and, say, 8 inches in width and height, forms the dark chamber in which is set up the object to be illuminated. In one of the square ends of the box are two round openings, so placed that their centers are 2½ inches apart, for the eyes of the person to be examined, and, close by, a larger one, 25 square centimetres, for the light-source. The latter opening is covered across on the inner wall of the box with fine white window-paper, and at a distance of 1½ inches from the paper, outside the box, stands a lighted wax-candle. The square of paper so illuminated serves as light-source for the objects which are to be placed in the box on the opposite wall. The magnitude of the light-source is alterable at will by means of diaphragms—pasteboard screens with openings—of definite dimensions, which are shoved close in front of the aperture.

"*Note.*—This is, in brief, the very simple apparatus, with which I instituted the investigations. For those who would construct a similar apparatus, the following directions may serve: In the upper wall of the box there was a neatly fitting trap-board of almost the breadth of the wall and 8 in. in length, through which the objects which had been fastened on pasteboard—strings of various thicknesses, black parallelograms and squares, various kinds of print—could be readily introduced. For object-carrier there was, inside the box, a movable wooden screen, hung vertically. On its anterior surface, two forward-springing clasps, furnished with grooves, received the sheet of pasteboard, slide-fashion. A wooden rod, an inch longer than the box, was fastened by one of its ends at a right angle to the back side of the screen, its other end extending backward, through an opening, to the outside of the box. By drawing this rod less or more outside the box, one could set the screen at any desired distance from the light-source and from the observing eye—such distance being at the same time shown on the protruding portion of the bar. The screens with openings were shoved down from above, likewise in a grooved arrangement, for which purpose there was a second trap-board in the upper wall of the box. Inasmuch as it was

necessary to keep the room in which the experiments were made as dark as possible, in order to avoid every kind of disturbing influence from other light on the eye to be investigated, and inasmuch as it was also necessary to see that no rays of light fell through the openings intended for the eye into the interior of the box, the light was enclosed by a kind of lantern, which, consisting of four boards, was fastened to the outer wall of the box. One wall of the lantern was made removable, after the manner of a sliding box-lid, for the sake of readier accessibility. Through the floor of the wooden lantern there passed a screw, vertically, whose upper end bore the light. In this way the candle with its flame could always be kept at the right height in front of the paper window. The two ocular openings in the anterior wall of the box had, each, a diameter of about 1 inch, and could be supplied with tubes enclosing convex or concave lenses. The purpose of this was to avoid the necessity of setting objects further from or closer to the light-source by way of adjustment to the varying conditions of refraction.''

Foerster then goes on to say, among other things, that the patient should always be kept in the dark for a number of minutes before his light-sense is investigated ''in order to allow the after-images of the daylight to pass away.'' Then, after a chapter on ''The Investigation of Sound Eyes,'' he devotes the remainder of the book to ''Hemeralopie.''

Thus much space I have given to Foerster's photometer and the beginnings of photometry in ophthalmology, because, although the importance of a careful investigation of the light-sense (especially in commencing affections of the optic nerve and retina) was, for a very long time, ignored, it is now beginning to attract the attention of the more earnest ophthalmologists, and will, as I venture to predict, be more and more adequately recognized in the further refinements of ophthalmic diagnosis.

Lateral Illumination.—This excellent means of diagnosis was first employed by Himly, who used a convex lens. The chief development of the method, however, is due to Helmholtz (who with it discovered a number of important changes which occur in the eye in consequence of accommodation) and Liebreich, who published a number of observations on the subject in 1855. We may add, for the sake of completeness, though not concerned at present with pathology, that Albrecht von Graefe, in 1855, described his use of the method in question for the purpose of determining the stage and consistency of cataract.

The Ophthalmoscope.—One of the most important aids in the study of ocular physiology, as well as the greatest ophthalmic instrument of all time, was the Augenspiegel, ocular speculum, or ophthalmoscope, invented by Hermann Helmholtz in 1851.[51] The history of this instru-

[51] The actual date of the invention of this instrument is 1850, late in the year; but the date of the little volume in which the invention was published to the world, ''*Beschreibung eines Augenspiegels,*'' is 1851, and, as a rule, the date of publication is regarded as the date of invention.

ment will be presented so fully in the article, **Ophthalmoscope,**[52] that only the following outline of the subject will be submitted here, and that much merely for the sake of a clearer connection of part with part in the present article.

Even in the earliest ages the eyes of certain animals had, as a matter of course, been observed to grow luminous in the dark.[53] Ancient writers, too (for example Pliny) remarked upon this circumstance, but either (like Pliny) did not attempt to give a reason, or else supposed that the eyes themselves had somehow made the light. Not till the time of Prévost, of Geneva (*circa* 1810) was it shown that the light from animals' eyes must surely be reflected light, since it disappears completely and in every instance in the dark.

Meanwhile, Jean Méry, of Paris, having accidentally (in 1704) held a cat under water, observed, first of all, that the pupil dilated (as a result of suspended animation), and then he beheld in its unparalleled glory the fundus of the animal's eye—the entrance of the optic nerve and all the splendid colors and delicate tracery of the visual dome. Méry understood quite well enough that something more than mere pupillary dilatation was necessary to account for the possibility of observing the fundus of the eye when the eye was under water. His explanation, however, of the "something more" was wholly erroneous. He believed, that is to say, that the view of the fundus was rendered possible by the water's filling up a multitude of tiny "unevennesses" on the anterior surface of the cornea. Five years later de la Hire stepped forward with the correct explanation. According to him, the water obviated the refraction of light by the cornea, so that all rays leaving a given point upon the fundus emerged from the eye not as parallel, but as divergent, rays. De la Hire also observed, incidentally, that the disturbing light-reflexes proceeding from a cornea *in aëro* are done away with by the water.

Then began a series of observations on the eyes of human beings. In 1796 Fermin observed a certain luminosity in the pupils of an Ethiopian albino. In 1816 Scarpa remarked upon a similar phenomenon in a certain disease of the fundus, and, one year later, Beer described the same condition fully, inventing therefor the expression "amaurotic cat's eye"--a term still in use. In 1836 Hasenstein first

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[52] See also on this head the very detailed and careful historical introduction to Dr. George M. Gould's "The Ophthalmoscope and The Art of Ophthalmoscopy" (in Norris and Oliver's "*System of Diseases of the Eye*," 1897, Vol. II, p. 63) also the interesting and otherwise excellent "Evolution of the Ophthalmoscope and What It Has Done for Medicine," by Samuel Theobald, M. D., of Baltimore (*New York Medical Journal*, June 22, 1901).

[53] A function of the *tapetum lucidum*.

produced a factitious luminosity by compressing the eyeball backward—making the eye, in fact, artificially hypermetropic. Then Beer, in 1839, remarked on the red reflection from the bottom of a human eye in a case of irideremia—i. e., total absence of the iris; and in 1846 Mr. Cumming reported a similar appearance in the human eye where the pupil had been dilated artificially.

Just a year earlier, however, Kussmaul, for the very first time in history, came forward with the true explanation as to why the pupil of an eye under usual circumstances, is black. He, that is to say, removed the cornea from an eye. Then, looking at the fundus through the pupil and the lens, he saw that the pupil was still all black. On removing the lens, however, behold, the fundus! From another eye he removed neither the cornea nor the lens, but extracted a portion of the vitreous. And then, as the fundus advanced, it came within his vision. The secret was out. It is solely the fact that the fundus lies at the focus of the refractive system of the eye, that keeps the fundus invisible and the pupil dark.

In the following year, a student in the London Hospital, named Cumming, performed a significant experiment. The person to be examined was set in a dark room at a distance of ten or twelve feet from an artificial light, and a screen so placed as to exclude the lateral rays. The subject of the experiment was then directed to gaze a little to the side of the light. Then Cumming, bringing his eye as close as he could to a line uniting the light with the eye that was under observation, beheld the "retinal reflex," as we of today would express it. Cumming also observed that, now and then, as the subject of the experiment would cast his eye about, in a certain fashion, the red appearance was exchanged for a silvery white—a phenomenon, of course, produced by the entrance into view of the optic nerve-head.

In the very same year, 1847, Brücke, of Vienna, passed a tube through the flame of a candle, and, looking through the tube, perceived the patient's fundus. He also reported the observation of a friend, Erlach by name, who had noted that when the reflection of an artificial light from the front of his spectacle lenses was cast upon the pupil of a friend who stood directly before him, the pupil was made to glare. Brücke had nearly—not quite—invented the ophthalmoscope.

The first ophthalmoscope was really invented by the English mathematician, Charles Babbage—the first, that is to say, in point of actual time, though not the first in point of admitted, or even admissible, priority. For, alas! poor Babbage, instead of reporting his great discovery himself, submitted it to the greatest ophthalmic authority in his

country at that day—no less a personage indeed than the world's most widely celebrated operator—Thomas Wharton Jones. And Jones reported against it!

Here is the story of the sad transaction, as given by Jones himself, in Oct., 1854, in an article entitled "Report on the Ophthalmoscope" (*Brit. and For. Medico-Chir. Review*, Vol. XIV, p. 426): "Dr. Helmholtz, of Königsberg, has the merit of specially inventing the ophthalmoscope. It is but justice that I should here state, however, that seven years ago Mr. Babbage showed me the model of an instrument which he had contrived for the purpose of looking into the interior of the eye. It consisted of a bit of plain [sic] mirror, with the silvering scraped off at two or three small spots in the middle, fixed within a tube at such an angle that the rays of light, falling on it through an opening in the side of the tube, were reflected into the eye to be observed, and to which the one end of the tube was directed. The observer looked through the clear spots of the mirror from the other end."

In 1850 the ophthalmoscope was again invented, this time by a very young German professor of physiology, whose name was Hermann Helmholtz. Helmholtz described this epoch-making instrument in a tiny, but cloth-bound, volume of only three and forty pages, entitled "*Beschreibung eines Augenspiegels zur Untersuchung der Netzhaut im lebenden Auge*" (Berlin), a volume which was published in 1851, so that this year, by the rule of publication in matters of priority, becomes the indisputable date for the greatest instrument which has ever been invented in all the ophthalmologic ages.[54]

Helmholtz's description of the normal fundus as beheld through his "Augenspiegel," is, in part, as follows: ". . . looking past the mirror a little to the inward side thereof, the observer will almost always recognize in the visual field one or two of the larger vessels. He causes the eye to turn to one of the near-lying figures, and notices whether he is brought nearer to the origin or to the branching of the vessels. While, in this way, he traces the vessels in the direction of their larger trunks, he comes at length to the place of entrance of the optic nerve. This distinguishes itself from the rest of the eye-ground

[54] The writer regards it as an especial honor that for himself remained the opportunity of providing the earliest translation of this volume into any language. (*Helmholtz's Description of an Ophthalmoscope*. Chicago: Cleveland Press: 1916.) May his pride be pardoned. Why this one almost supernal document in ophthalmology should have lain so long neglected as to the matter of translations is one of the mysteries of scientific literature. But true it is that, in England, only a five-page abstract of the book had appeared, in July, 1852, by Dr. W. R. Sanders, in the "*Monthly Journal of Medical Sciences*," and, in America, a shorter abstract still, in July, 1853, in the "*American Journal of the Medical Sciences*." Only these, and, now and then, in book or article, a tid-bit of quotation.

by its white color, for it is not covered with pigment and a fine vascular network, but here the white cross-section of the nerve lies wholly free, at the very most shot through by tiny, isolated vessels. Mostly to the inner side, near by, the arteries and veins of the retina press forward from the depths. At times one sees a portion of the vessel still hiding in the substance of the nerve, and understands that, in the living, this substance is decidedly transparent. One distinguishes the two kinds of vessels from each other by the brighter color of the blood and the double contours of the walls in the arteries and in their first ramifications. I have not been able to recognize pulsations with certainty. The first main branches of the vessels border the optic nerve at its inner side, in order to spread out later, above and below, across the retinal field. The appearance of the sharply peneiled red vessels on the clear white ground is of surprising elegance.'' We might perhaps be pardoned if we went considerably farther than the phlegmatic Teuton, we who have seen the picture after him, and exclaimed with the Italian priest who was entering the Freiburg Minster, "*Vere, hic est domus Dei et porta cœli!*" Even, in fact, the dome of the star-set firmament itself no more plainly shows "His handiwork" than does the living dome of vision in the human eye.

For a description of this miraculous instrument of von Helmholtz, the reader is referred to the article, **Ophthalmoscope.**

It remains to be added merely that the first to write upon the subject of the ophthalmoscope, after the distinguished inventor himself,[55] was Ruete, who, in 1852 (D. Augenspiegel u. d. Optometer) invented and reported the "indirect method." The "Rekoss discs" (i. e., the rotary discs containing lenses) were introduced by an instrument-maker of Königsberg, named Rekoss, and described by the original inventor of the instrument himself, in Vierordt's *Archiv*, in 1852. Epkens, in 1853, described for the earliest time the silvered mirror from which a little of the silver had been removed in the center, to make a peep-

[55] Concerning the strangely unfavorable reception which, at first, was given by the majority of ophthalmologists to the ophthalmoscope, there has come to light a rather considerable literature, which, as a matter of course, we cannot enter into in this article. The following anecdote, however, which was sent to the writer by Dr. Theodore Hough, of Charlottesville, Va., in a personal communication, and which has not, so far as the present writer knows, as yet appeared in print, would seem to be worthy of remembrance: "I wonder if you ever heard that fine old gentleman, Dr. B. Joy Jeffries, of Boston," says Dr. Hough, "tell of the time he came back from study under Helmholtz and undertook to give before a medical society an account of the ophthalmoscope. It provoked very active discussion, and the arguments for and against its use became quite heated. In the course of this, one old doctor sitting next to Dr. Jeffries forgot that Jeffries had read the paper and turned around to him and thus relieved his feelings, 'I'd shoot any man who dared to use that infernal instrument on my eye!'"

hole. (Helmholtz's mirror was simply a series of plates of unsilvered glass laid one upon another.) Then followed a series of instruments, for descriptions of which the reader is referred to the article **Ophthalmoscope**—Coccius's (in 1853) Jaeger's (in 1854) Stellwag's von Carion (in the very same year), Liebreich's (in 1855), Strawbridge's (of Philadelphia, in 1871). Wadsworth, of Boston, invented the "mirror obliquely set" which enables the observer today to look straight through the lenses instead of at an angle. The latest and one of the greatest improvements lay in the substitution of the direct (electrical) light for light reflected from a separate source. For this immensely valuable arrangement we are indebted to Dennett, of New York. Meyrowitz and De Zeng have introduced improvements in the original electric light ophthalmoscope, and Charles H. May has improved the illumination greatly, making it solid and free from reflex, shadow, and images of the lamp-filament. The instrument of May is also very light and simple.

A great addition to our powers of diagnosis was made by the introduction, at the hands of Himly (the re-discoverer) in 1801 of (locally engendered) artificial mydriasis in ophthalmology.[56] The drugs he employed were the extract of hyoscyamus and also that of belladonna. Slowly the method began to be employed, not only in connection with the cataract operation, but also for the searching out of pathologic alterations in the lateral parts of the crystalline as well as to determine the presence or absence of posterior synechia. After the discovery of the ophthalmoscope, the use of artificial mydriasis for the purpose of rendering easier a thorough examination of the deeper portions of the eye became quite general. Later cocain, and then homatropin (a synthetic product produced by Ladenburg in 1879) were employed in place of belladonna or its alkaloid atropin (first isolated by Mein in 1831).[57]

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[56] In his "*Ophthalmologische Beobachtungen und Untersuchungen*" (Bremen, 1801). Himly was not the first to produce an artificial mydriasis. Even in ancient times, the enlargement of the pupil was resorted to by women for purposes of beautification (a fact adverted to by Galen, XII, 740) and, before the time of Galen, old Archigenes seems to have understood that an artificial enlargement of the pupil will often improve the vision of a patient who is suffering from cataract. Loder, of Jena, in 1796, discovered, or possibly re-discovered, the use of artificial mydriasis as a preparation for the extraction, or depression, of cataract, and so, too, did Reimarus of Hamburg (independently again) in the following year. Then came Himly, beneath whose influence the use of this procedure began, though still very slowly, to become general.

[57] The following history of some of our more important alkaloids may not be uninteresting to ophthalmologists: Strychnin was isolated from the St. Ignatius beans by Pelletier and Caventou in 1818; brucin, from false angostura bark, and veratrin from Cevadilla seeds and white hellebore root, in 1819—both by the same investigators who isolated strychnin, and who also, in 1820, succeeded in

Tests for the Acuteness of Vision.—These really began with Heinrich Küchler, the inventor of test-types, who, in 1843, described the letters which he had invented and actually employed in his practice. By means of this simple device he had been enabled to state, in number fashion, the visual acuity of each eye and of both eyes, and to express the relative, or proportionate, acuity of either eye as compared not only with its fellow, but also with the average acuity of a number of normal eyes, and with the former acuity of the same identical eye, as shown by earlier tests. Küchler's cards, however, were only employed for the testing of near vision. The first to publish a complete collection of test-types was Ed. v. Jaeger, of Vienna, in 1854. The first to state upon the card, next to each row of letters, the distance at which that row could be discerned by the normal eye, was Stellwag von Carion, of Vienna, in 1855. Snellen, of Utrecht, finally, put the cap upon the sheaf by the invention of letters which, from above downward and also from side to side were composed of five (in the same line equally large) blocks, or square units, each block, at the normal distance (which was expressly stated for the line) subtending an angle of exactly one minute.[58]

The trial-case, oddly enough, was invented by a general-practitioner-specialist Fronmüller by name, and in the very identical year that saw the earliest sheet of test-types, 1843.[59]

Finally, we have to mention the discovery of the visual purple, by Boll, in 1876.

Pathology and Diagnosis.

To Scarpa, as we have seen, when examining that excellent author's text-book, the pathology of the eye was just about as vague and ill-defined as it was to the Saracenic writers or even to Aëtius and old Galen. It failed—for a single matter—to distinguish any ophthalmic inflammation from any other in accordance with the anatomic structures involved. Thus Scarpa, for example, speaks only of ophthalmia interna and externa. Retinitis, iritis, etc., were wholly unknown to him. This great deficiency was soon supplied by Wardrop, an oph-

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isolating cinchonin and quinin from cinchona bark. Caffein and codein were isolated by Robiquet in 1821; thein, by Oudry in 1827.

[58] For the later sorts of test-types, down to and including the very latest, and, in many respects, the best—Ewing's modification of the "three-line one-and-five-minute test-objects" of Snellen, see, in this *Encyclopedia*, **Test-Types.**

[59] For an English translation in full of Fronmüller's article, "On the Selection of Spectacle-Lenses," see Fronmüller, in the Appendix to this *Encyclopedia*. For Fronmüller's biographic sketch, however, see **Fronmüller**, in the body of the work.

thalmologist of Edinburgh and London, who, in his very remarkable treatise, "*Essays on the Morbid Anatomy of the Human Eye*" (Vol. I, Edinburgh, 1808; Vol. II, London, 1818) speaks of the special inflammations of the various anatomic structures of the eye—inflammation of the iris, keratitis, etc. In fact, it is in this work that the term, "keratitis," is first to be found in history. Wardrop, however, is weak in the matter of classification according to constitutional etiology, though he does acknowledge the existence of "scrofulous," "venereal," and similar sorts of eye affections. This deficiency, however, was more than supplied by Joseph Beer, of Vienna, in whom the old-time "humoral" theory of disease still ruled with a rod of iron. Hence in the "*Lehre der Augenkrankheiten*" we read not only of venereal and scrofulous eye diseases, but also of psoric, bilious, scorbutic, and hemorrhoidal, yes and even of such composite affairs as syphilo-scorbutic, bilious-hemorrhoidal, and rheumato-scrofulo-syphilitic. Indeed for a time the ophthalmologists of Europe would seem to have been divided into schools with regard to this particular matter of the classification of eye-diseases—i. e., the English school, which, following Wardrop, would hear of nothing (or little) but an anatomic basis, and the Teutonic school, which, following Beer, would know of eye diseases only, or mainly, as related to this, to that, and to the other "dyscrasia."

The upshot of the matter was that both these classifications were found of value, much was retained of each of them, and much (very much indeed) has been later added unto them. Thus, for example, in the single matter of conjunctivitis, there is a very strong tendency today to classify as far as possible on a micro-organismic basis—pneumococcus conjunctivitis, Koch-Weeks bacillus conjunctivitis, influenza bacillus conjunctivitis, and diplobacillus (or Morax Axenfeld) conjunctivitis.

The conjunctiva.—The cause of ophthalmia neonatorum, as we have seen already, was pointed out by Quelmalz as early as 1750, in his truly immortal dissertation "De Coecitate Infantum Fluoris Albi Materni ejusque Virulenta Pedisequa." Prior to his time, this terrible disease was ascribed to colds, traumatism, foul air, etc. The great discovery, however, went unheeded for a very considerable time. Thus, as we saw, when reviewing the text-book of Scarpa, the beginning of the 19th century was wholly oblivious to Quelmalz's discovery. Even as late as the text-book of Mackenzie, the situation was much unchanged, for that celebrated author thought that the disease was produced by the washing of the infant's face with soap, some of the soap presumably getting into the eye. Only the discovery in 1879 of the gonococcus

by Neisser put an end to the otherwise interminable speculation and discussion.

A similar war of words raged in the first two-thirds of the 19th century about the etiology of the *gonorrheal ophthalmia of adults*. Astruck, Wardrop, Jüngken, and many others attributed the affection (properly, as now we know) to direct inoculation by means of gonorrheal pus. Others, however, Sichel for example, would have the explanation to lie in what was called "metastasis"—i. e., a hidden, or internal, conveyance of the virus to the conjunctiva by way of the blood vessels. Decondé and Cunier thought the trouble due to "l'infection miasmatique." "Sympathy" was yet another explanation.

The cause of *trachoma* is still unknown. The introduction of the disease into European countries by the soldiers of Napoleon returning from Egypt resulted, very early in the century, in a fearful epidemic not merely of the disease in question, but also of learned speculation about its infectious, or non-infectious, character, its endemicity, and, most of all, its origin, or, to speak more exactly, its etiology. Some attributed the trouble to dust, others to light, others to foul or miasmatic air, etc. With the advent of the germ theory of disease, the affection was thought, of course, to be produced by micro-organisms, and even at the present time, we hold, in a general way, the same opinion. But whether the affection is one or several, whether it be produced by one or a number of micro-organisms, or whether in fact it is really produced by micro-organisms at all, we do not know. Sattler and von Michel, indeed, of recent years, ascribed the disease to a small double coccus, called by them "the trachoma coccus." Then came Muttermilch, with his fungus "miscrosporon trachomatosum." In 1907, moreover, Halberstaedter and Prowazek ("Ueber Zelleinschlüsse Parasitärer Natur beim Trachom," *Arbeiten aus dem Kaiserl. Gesundheitsamt*, Bd. XXVI, 1, s. 44) discovered in the epithelial cells of trachomatous conjunctivæ certain supposedly parasitic inclusions which they called "trachoma bodies" (Trachomkörperchen) and which they believed to be the specific micro-organisms for trachoma. None of these supposed discoveries of specific organisms, however, has really stood the test of time, and the cause of trachomatous conjunctivitis is as much a mystery to the recent graduate in ophthalmology as it was to Father Hippocrates.

Keratitis.—The name of this affection, as we have seen, was a word unknown to Scarpa, as was the affection itself. The term was invented in 1808 by Wardrop, who, in fact, as already stated, was first in history to classify the various eye-ball inflammations according to the structures attacked. Scarpa, as the reader remembers, knew only

"internal and external ophthalmia." Wardrop even described the inflammation of the membrane of Descemet—descemetitis. Mirault, in 1823 and again in 1834, published his classical "*Mémoire sur la Kératite,*" etc., which gave a tremendous impetus to the study of keratitis generally. Finally, Heinrich Bruno Schindler, in 1836, published in Vol. I of von Ammon's "*Monatschrift,*" "Die Entzüundungsformen der Menschlichen Hornhaut," in which he supplied the first description of "interstitial keratitis." Schindler's work is especially valuable in the matters of symptomatology and diagnosis.

Some of the more important developments in the pathology of keratitis and ulcer of the cornea, chiefly since the epoch-making work of Schindler, are as follows:

The senile nature of the *arcus senilis corneæ* was first made clear by Schoen in 1831. The symptom itself, of course, was known in the earliest ages.

As late as 1858 it was held by so great a man as von Graefe that the cornea was never affected by syphilis. The mistake was corrected for good and all by Sir Jonathan Hutchinson in his classical work, "*Clinical Memoir on Certain Diseases of the Eye and Ear Consequent on Inherited Syphilis*" (1862).

Herpes corneæ was first described by Horner, who exhibited a case before the Heidelberg Ophthalmological Society in 1871, while, in the following year, Schmidt-Rimpler distinguished from this disease the so-called neuralgic corneal herpes.

Keratomycosis aspergillina was first described by Leber in 1879.

Filamentous keratitis was first described in 1882 by Leber, who presented a case before the Heidelberg Ophthalmological Society.

Macular keratitis was first described by Fuchs in 1889. Its cause remains a mystery, but is probably the streptococcus.

Serpiginous ulcer of the cornea was first described by Saemisch, but its causative connection with the pneumococcus was first shown by Gasparini not until 1893.

Pannus.—Scarpa believed that pannus was something like pterygium—an actually idiopathic affair. Beer, in his classical text-book, (1817) showed the dependence of this affection, or, rather, symptom, on some previous affection of the lids, especially the upper. Ritterich, till nearly 1860, furnished a number of useful observations on the pathology of pannus.

The Sclera.—Until well into the 19th century, inflammations of the sclera were confounded with those of the conjunctiva. Scleritis was first described by von Ammon in 1829, better by Sichel in 1847, by

Wilde in 1854, and by Pilz in 1862, while Wharton Jones (in the last-named year) made some further studies of this disease.

The posterior scleral staphyloma of Scarpa we found described in Scarpa's text-book. Von Walther, in 1822, described the *staphyloma corporis ciliaris*, which, of course, involves the sclera, and von Ammon, in 1841, in his monumental "*Klinische Darstellungen der Angeborenen Krankheiten des Auges u. der Augenlider*" (Berlin, folio) described the posterior scleral protuberance of von Ammon. This information is to be distinguished from the posterior staphyloma of Scarpa both by the fact that it is always congenital, while Scarpa's staphyloma is invariably acquired, and also by the fact that it lies not quite at the posterior pole of the eye (as does the staphyloma Scarpæ), but a little below that spot.

The iris and ciliary body.—The term, iritis, was introduced by Johann Adam Schmidt, of Vienna, in 1801.[60] The first circumstantial description of the disease was supplied, however, by Joseph Beer, also of Vienna, in 1813. Travers, then, an Englishman, in 1816 and again in 1818, and von Ammon in 1835, 1839, and 1843, developed our knowledge of this affection with even greater particularity. Von Ammon, in 1838, introduced the terms, iridodonesis (trembling of the iris), iridoraesosis (iridic atrophy) and iridoncosis (iridic hypertrophy). Beer, also, in his various writings, excogitated from his humoral theory (a relic of the days of old Hippocrates) such terms as arithritic, rheumatic, and syphilitic iritis, and even syphilo-scorbutic, scrofulo-arthritic, and syphilo-mercurial varieties.

The term cyclitis was supplied by Tavignot in 1844, also kerato-cyclitis and irido-cyclitis.

The deeper structures of the eye.—An accurate pathology of the deeper portions of the eye was only possible as a result of the invention by Hermann Helmholtz, in 1851, of the greatest instrument which has ever been devised in the history of ophthalmology—the ophthalmoscope. The possibilities of the "Augenspiegel" were, in fact, perceived to a large extent by the inventor himself, who, in the tiny book wherein he described the revolutionary device, set forth the following by no means unfounded hope: "After deciding what, in the healthy eye, can be made out concerning the nature of the retina, I have no doubt that one will be able to recognize all such disease conditions as permit of recognition by the sense of sight in other transparent parts—for example, the cornea. Increased repletion of the vessels and vascular varicosities must prove easy to make out. Exudates into the substance

[60] The word, "iris," in its modern sense, was, as the reader will remember, introduced by Winslow in 1721.

of the retina, or between that structure and the pigment membrane, must yield themselves to observation, very much as affections of the cornea do, by their brightness against a dark ground. If they lie in part before the retina, they will then enclose its vessels in a veil. I here recall that, according to Brücke, the recent retina is just about as transparent as the other ocular media, and that, apart from its vessels, it is only visible in our experiments because it is strongly illuminated on the deep-black ground of the pigment membrane. Fibrinous exudates, which are nearly always less transparent than the ocular media, must also for that reason, when they lie in the fundus of the eye, considerably strengthen the reflex. Then, too, I believe that opacities of the vitreous body will be much more easily and certainly recognizable, partly by the illumination of a reflecting glass-plate, partly by the ophthalmoscope. One will even be able to determine with ease, from the indistinctness of the image of the flame and of the retinal vessels, the degree of the opacity. If, in the case of such an opacity, scintillating particles have detached themselves, then too a person will be able to take note of these. In brief, I believe that I may hold the expectation not to be exaggerated, that all the alterations of the vitreous body and of the retina which, until now, have been found in cadavers, will also permit of recognition in the living eye—a possibility which appears to promise the most remarkable advances for the hitherto undeveloped pathology of this structure." [61]

Now the whole of the deeper pathology of the eye, as brought to view by means of the ophthalmoscope of Helmholtz, also by the similar instruments of various later inventors, is shown with sufficient clarity and fullness in a number of the non-historic portions of this work. We may, however, advert to a number of the more important ophthalmoscopic discoveries, together with some of the dates of their makings, as follows:

The first to discriminate sharply incipient affections of the lens from diseases of the fundus, was Ruete, in 1852.

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[61] From the writer's (which also happens to be the only) translation of the work in question (Chicago, Cleveland Press: 1916) the following footnote to this passage may also be repeated: "Probably the most significant sentence ever penned by an ophthalmologist. How gloriously the great man's prophecy has been fulfilled is known not merely to specialists and general practitioners, but even, in some degree, to first-year medical students and the educated portion of the laity. In fact, there are just two kinds of opthhalmology, that which came before and that which followed after Helmholtz's '*Beschreibung eines Augenspiegels.*' "

Interesting it is to note that even the myriad-minded Helmholtz had no suspicion at all of the value which his instrument was destined to exhibit in the matter of the diagnosis, symptomatology, etiology, and prognosis of many of the diseases of organs which are far removed from the visual apparatus, and also in affections of the system in general.

Detachment of the retina was first described by Coccius in 1853.

In the very same year Donders supplied the first description of pigmentary degeneration of the retina, together with its characteristic symptom, nyctalopia. Then von Graefe, in 1856, provided the second, and by far a fuller, report.

The condition of the head of the optic nerve in advanced glaucoma was first described in 1853—i. e., by Ed. von Jaeger. He, however, committed the error of supposing that the nerve was tumefied, instead of excavated. The first to determine that the change in the nerve consisted in a "hollowing out," "excavation," or "cupping," was the indefatigable Albrecht von Graefe (in 1855), who also, in the previous year, had described the arterial and venous pulses in the glaucomatous nerve-head.

In 1855, furthermore, Liebreich, an assistant to von Graefe, first described a case of *apoplexia retinæ*, the result of thrombosis of the retinal veins.

The retinal changes dependent on nephritis were first observed with the ophthalmoscope by Heymann in 1856 (*Prager Vierteljahrsschr.* Jahrg. XIII, 1, p. 102; also *Arch. f. Oph.*, 1856, II, 2, p. 131). Liebreich, three years later, gave a very detailed description of the fundus changes in this disease, as well as an excellent ophthalmoscopic picture of them.[62]

Three years later syphilitic retinitis was first described by Jacobson, and, the year following (1859), von Graefe reported the earliest case of embolism of the *arteria centralis retinæ*, following this, in 1860, with a description of choked disc.

In 1861 Ed. von Jaeger provided the first description of atrophic excavation of the optic nerve papilla.

Finally (for a finally must come) Foerster, in 1862, described a case of syphilitic choroiditis.

Then came a host of investigators, announcing numerous discoveries, some fanciful, some real, some of much and some of trifling, value, but which cannot here be listed.

While speaking of the services rendered by the ophthalmoscope to our knowledge of the deeper tissues and deeper affections of the eye, we must not neglect to exhibit, in very brief form to be sure, the history of *glaucoma*, a history which, as one may say, was almost

[62] Already—i. e. in 1827—nephritis had been described by Richard Bright (*q. v.*) and the pathologic anatomy (observed *without* the ophthalmoscope) of the ocular changes in nephritis were given most thoroughly by Rud. Virchow in Sep., 1856 ("Zur pathologischen Anatomie der Netzhaut und des Sehnerven," in Virchow's *Archiv*, X, pp. 170-194). Virchow's article, however, was published later in the year than the article by Heymann.

wholly constructed as the result of the invention of Helmholtz's little instrument. It was, moreover, built up in a very few years.

We have already seen that, in antiquity, as well as throughout the middle ages and also the modern period as far as to the 19th century, the disease in question was wholly confounded with cataract, hypopion, and amaurosis. Even the very word, "glaucoma," though used by the ancients, is not, so far as I have been able to ascertain by the carefullest searching, to be found in Scarpa's book.

Fabini, so far as I know, was the earliest man in history to speak of the hardness of the eyeball in glaucoma. This he did in his "*Doctrina de Morbis Oculorum*," in 1831.

To William Mackenzie, however, the world is indebted for the earliest recognition of increased intraocular tension as the *essential factor* in glaucoma, as being, that is to say, of the very essence of the disease. Thus, in "*A Practical Treatise on the Diseases of the Eye*" (1830) at p. 472: "The eyeball *always* feels firmer than natural; while in cataract it presents its usual degree of resistance to the pressure of the finger." In the edition of 1854, moreover, the same authority says: "When the finger is placed on such an eye, it feels as hard as pebble, indicating that serous effusion has taken place into the vitreous body, augmenting the contents of the eyeball beyond their normal quantity."

Mackenzie invented, and steadily employed for a number of years, paracentesis of the sclera, or of the cornea, in accordance with his theory of increased intraocular tension, and was followed in his method of treatment by numerous ophthalmologists both in Europe and in America, but the sole relief which any of these obtained was purely temporary—one might almost declare "momentary."

After the invention of the ophthalmoscope, Jacobson, in 1853, gave forth a dissertation in which he embodied the results of a careful ophthalmoscopic investigation of glaucoma, but declared that his findings were *nil*.

Then came, as I have said already, von Jaeger, in 1854, with his work, "*Ueber Staar und Staaroperationen*," and a description of certain papillary changes, which were, as we know today, excavations, but which that early investigator mistook for protuberances.

In the very same year von Graefe fell into the same error (*Archiv f. Oph.*, I, 1, p. 373).

Weber, next, in 1855, invented the method of intraocular mensuration by means of parallactic movement, and also improved the method of measuring levels in the eye by means of the strength of lens required to see each given *niveau* distinctly.

Thereupon von Graefe retrieved himself. Adopting, that is to say, the mensuration methods of Adolf von Weber, he determined (in 1855) that the actual condition of the nerve-head in glaucoma is truly a condition of excavation, and not at all of salience.

Already, by the same investigator (in 1854) had been discovered the arterial and venous pulses of the disc in glaucoma—a striking phenomenon which, however, Donders, in the very same year, had succeeded in reproducing in the healthy eye, by means of gentle finger-pressure applied to the globe, and gradually increased.

The secret of glaucoma was now "out." The Mackenzie theory had been absolutely confirmed. The way to cure glaucoma was, in fact, to find some way whereby the pressure within the globe could be diminished permanently.

Von Graefe found the way. The date was 1856—a date which should be remembered together with that of the ophthalmoscope invention (1851) and that of the earliest extraction of a cataract (1748).

The manner of the finding will be described hereafter when we come to speak of 19th century ophthalmic surgery. At present we are speaking of the pathology and diagnosis of that century.

To von Graefe we are also indebted for the most of what we know about the visual field in glaucoma (*Archiv f. Oph.*, 1856).

To Sir William Bowman, moreover, we owe the earliest attempt at tonometry. He, that is to say, in 1862 ("On Glaucomatous Affections and Their Treatment by Iridectomy," in the *Brit. Med. Jour.*,) made known the method of noting and grading the pressure within an eye, by means of the following nine symbols: T3, T2, T1, T1?, Tn,—T1?,—T1,—T2,—T3.

Since Bowman's day a number of ingenious instruments[63] have been devised for the taking of the tension more accurately, but still a good many most excellent diagnosticians prefer their own two forefingers placed over the closed upper eyelid, precisely in the manner of Bowman.

A number of pathologic (including diagnostic) matters remain to be considered, but will have to be treated with the very greatest brevity. First of all, the so-called *disease of Basedow*, or *exophthalmic goitre*, is an affection which was wholly unknown till the 19th century. Its history, in brief, is as follows:

1. Giuseppe Flajani, in 1802, reported in his "Collezione d'Osservàtioni e Riflessioni di Chirurgia," three cases of cardiac palpitation with associated goitre.

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[63] See, in this *Encyclopedia*, **Tonometer**.

2. Caleb Hillier Parry, a physician of London, in 1825, made a report of thirteen cases of associated goitre and tachycardia. In only a single case, however, had he observed a protrusion of the eyes. Nevertheless, this was getting pretty close to the discovery of Basedow's disease.

3. Then came Basedow, who in 1840, published in "*Wochenschrift d. Heilkunde von Casper,*" No. 13, at pp. 197-204, and No. 14, pp. 220-228, an article entitled "Exophthalmos from Hypertrophy of the Orbital Cellular Tissue." In this article he remarks: "I have often had occasion to observe an exophthalmos, which had been communicated to the orbit from disease of the cellular tissue in some other portion of the body, that is to say, through some special hypertrophy, which, in consequence of a disease of the heart or of the large vessel-trunks, appeared to arise in various glands and parts composed of cellular tisue." Reporting, then, in some detail, a number of cases of the peculiar disease in question, he continues:

"I regard this hypertrophy of the cellular tissue behind the eyeballs as a phenomenon secondary to a disordered circulation and an improper mixture of the blood, as a dyscrasia, which, turned in that direction by a latent scrofula, expresses itself in morbid glandular proliferations together with obstructions in the cellular tissue."

A great contest soon arose, after the publication of this remarkable article by Basedow, regarding the question of priority—a question which is still unsettled. To complete the history of the matter, however, we shall have to add that—

4. Robert James Graves, a physician of Dublin, in 1835, delivered a number of lectures on cardiac palpitation combined with enlargement of the thyroid gland. He reported a number of cases, and remarked that he had often observed in connection with the two chief symptoms a third—namely, protrusion of the eyeballs. These lectures, according to the partisans of Graves, entitled the distinguished Irishman to the honor of having the disease in question forever bear his name. The partisans of Basedow, on the other hand, rely upon two facts, which, as they contend, debar the Dublin physician from the honor which, as a rule, the medical profession of Ireland, of England, and, for the most part, of America, would be pleased to see accorded him. These facts are: (1) Graves did not regard the protrusion of the eyes as an essential element, or symptom, of the disease (and, in fact, it isn't). (2) Graves' lectures did not appear in print until 1843—three years later than the article by Basedow.

The study of *achromatopsia*, or *Daltonism*, was begun in the 18th century—to be precise, on the 31st day of October, 1794—by John

Dalton, a physicist and chemist, who was himself afflicted with the very distressing condition. The story about the discovery of his affection runs as follows: "When a boy, being present at a review of troops, and hearing those around him expatiating on the gorgeous effect of the military costume, he asked in what the color of the soldiers' coat differed from that of the grass on which he trod; and it was the derisive laugh and the exclamations of his companions which this question called forth that first made him aware of the defectiveness of his eye-sight."[64] Dalton reported his own case in an article entitled "Extraordinary Facts Relating to the Vision of Colours" (*Memoirs of the Literary and Philosophical Society of Manchester*, Vol. 28, 1798). Achromatopsia was considered next by Young, in 1807—but its study was only taken up again after the lapse of sixty years—i. e., by Helmholtz in 1867. Then came Donders in 1871, Favere in 1873, Holmgren in 1877, Cohn in 1878, and Jeffries (of America) in 1878. To the latter is due the world-wide movement for the exclusion of the color-blind from responsible positions, the proper performance of the duties of which demand the possession of an accurate sense of color.

For the various theories of color-blindness, such as the Young-Helmholtz theory, the Hering and the Holmgren theories, see **Color-blindness** in this *Encyclopedia.*

The *ocular disturbances which arise from undue seminal losses* were studied first by Lallemand. His results were embodied (in 1825) in his "*Observations sur les Maladies des Organes Génito-Urinaire*" (2 parts, Paris and Montpellier).

The *rodent ulcer of the face*, commonly known as "*Jacob's ulcer,*" or "*cancroid ulcer,*" was described by Arthur Jacob, of Dublin, Ireland, in 1827, in an article entitled "Observations Respecting an Ulcer of Peculiar Character, which Attacks the Eye-Lids and Other Parts of the Face." This article is reproduced *in toto* in this *Encyclopedia,* Vol. IX, page 6695.

Sympathetic ophthalmia began to be studied by Wardrop in 1818 and by Mackenzie in 1830, though Benedict Duddel, in 1729, had referred to the affection unmistakably, even as Fabricius ab Acquapendente (in 1613), Bartisch (in 1583) and Avicenna (*circa* 1000 A. D.) had also done. Next von Ammon investigated the subject with somewhat greater particularity, declaring the affection to be either an iritis or a uveitis. In 1841 the only positive remedy, or, rather, prophylaxis, for this affection, was invented by Bonnet—enucleation. Numerous theories concerning the etiology of this affection have been promulgated by as many writers—e. g., the old-time optic nerve theory

[64] *New Am. Enc. Brit.,* 20th Century ed., III, 904.

of Adolf Alt, the ciliary-nerve theory of Müller, the bacterial theories of Arnold, Leber, and Schmidt-Rimpler—yet the cause of ophthalmia sympathetica is as much of a mystery as it was in the very beginning.

An important means of general diagnosis involving a condition of the eyes, was described by Jonathan Hutchinson in 1862—the so-called "*Hutchinson's triad.*" It consists of syphilitic teeth, labyrinthitis, and interstitial keratitis.

Seven years later there was introduced (i. e., in 1869) a valuable means of diagnosis now well known to every ophthalmologist—the *Argyll Robertson pupils.* These are pupils which respond to accommodation and convergence, but not to light. The passage in which the discovery was announced runs as follows: "On examining the eyes I found both pupils contracted to little more than pin-points, the right rather the smaller of the two. The irides were light-colored, and apparently healthy in structure. I could not observe any contraction of either pupil under the influence of light, but, on accommodating the eyes for a near object, both pupils contracted." (On an Interesting Series of Eye-Symptoms in a Case of Spinal Disease, etc., by D. Argyll Robertson, M. D., F. R. C. S., Lecturer on Diseases of the Eye, Edinburgh; *Edinburgh Med. Jour.*, XIV, Part 2, p. 696, Feb., 1869.)

The importance in diagnosis of many of the instruments and processes which have already been described under the heading, "*Physiology.*"—e. g., perimetry, photometry, the trial-case and test-types—is sufficiently apparent without a renewed discussion of such matters in this place.

The Roentgen ray as a means of diagnosis in cases of foreign bodies in the eye, of pus accumulations in the orbit, and of various empyemas (open or closed) in the nasal accessory sinuses, is well discussed through all its phases in the non-historic portions of this work. We may, however, add, on the purely historical side of the subject, that the rays in question were discovered by Professor Roentgen, of Vienna, in 1895; that at first they were not supposed to be applicable in eye work,[65] because of the bony obstructions by which the eye was almost wholly encompassed, that the first successful attempt to show a foreign body in the globe of the eye by means of a skiagraph was made by Dr. F. H. Williams, of Boston; that the first attempt to remove from the eye a foreign body which had first been shown in a radiograph, was per-

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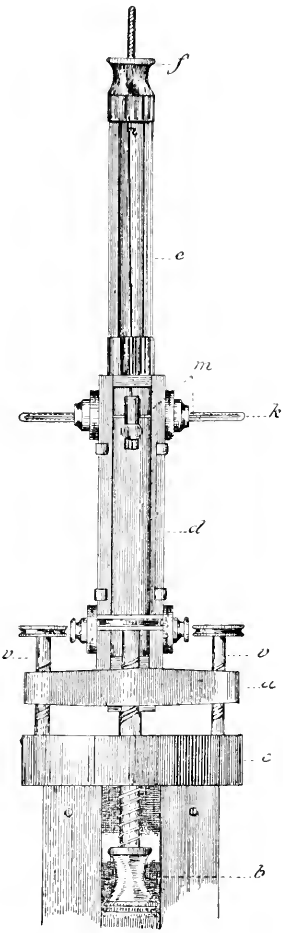
[65] See, for example, the unfavorable reports of Dariex and Rochas. ("Sur la perméabilité de l'Oeil aux Rayons de Roentgen," *Ann. d'Ocul.*, 1896, Vol. 115, p. 218.)

formed by Dr. Chas. H. Williams,[66] also of Boston, and that some of the later successful laborers in this field were Exner, King, de Schweinitz, Thompson, Sweet and Oliver.



The Sideroscope of Asmus.

The sideroscope had already been introduced (i. e., into ophthalmology) by Thomas R. Pooley, of New York. A later and better instrument than Pooley's was that of Asmus. There were also the magnetometer of Gérard, the sideroscope of Hirschberg and Janssen's siderophone. But all these instruments were oversensitive, could not

[66] Williams, "A Case of Extraction of a Bit of Copper from the Vitreous, Where X-rays Helped to Locate the Metal" (*Trans. Am. Oph. Soc.*, 1896, Vol. VII, p. 708).

be used in the neighborhood of a powerful electric current, and, finally, have been supplanted, to a very large extent, by the very much more trustworthy Roentgen rays.

Just about the close of the 19th century, the importance of mucoceles and empyemata of the nasal accessory sinuses as factors in the production of a number of serious eye diseases began to be taken note of. Some of the earliest workers in this field were Berger-Tyrmann, Hajek, Vossius, Winckler, Ziem, Loeb, Ballenger, and Brawley. To Brawley we are indebted for the suction method of diagnosing empyemata of the sinuses in question. Foremost in the subject of *injuries to the eye* are Wagenmann, of Heidelberg; Würdemann, of Seattle, and A. Maitland Ramsay, of Glasgow, whose works upon this subject are simply indispensable. In *visual economics* the leaders have been Hugo Magnus, of Breslau; Harry V. Würdemann, of Seattle, and E. E. Holt, of Portland, Maine. See, in this article, the various sections on the history of the magnet operation, the Roentgen ray, antisepsis and asepsis, as well as the various relevant non-historic articles in this *Encyclopedia.*

Prophylaxis and Treatment (Including the Treatment of Errors of Refraction).

This is a very large subject, which might be pursued to intolerable length, and of which I shall here advert to but two or three chief illustrations.

Prophylaxis.—One of the most important measures which have ever been discovered for the prevention of serious affections of the eye has been already referred to, under the heading, *Pathology*—namely enucleation as a means of forestalling that fearful occurrence, sympathetic ophthalmia. This great boon was presented to the world by Amédé Bonnet in 1841.

The most important, however, of all the means for prophylaxis which have been discovered in ophthalmology is *Crédé's solution.* It is scarcely necessary here to add that the liquid in question is simply a weak solution of silver nitrate, and that, simple as the solution is, it has saved, beyond the slightest peradventure, innumerable multitudes of human beings from the curse of incurable blindness. The date of this discovery is 1884; the same as that of Koller's discovery of cocain as an ophthalmic anesthetic. *Annus Mirabilis!*

Crédé's important discovery was based on the view of Nöggerath, of New York, "that the most of the extremely frequent acute and chronic

inflammations of the female genitalia depend on clap-infection.'"[67] Also, on the further view of Nöggerath "that, for the infection of the woman, a clap in the height of its development is not necessarily presupposed, for even a mere gleet, which, hitherto, had been regarded as innocent, is quite sufficient, and indeed the possibility of contagion is present in cases in which the clap seemed long to have disappeared —a so-called 'latent clap' in fact remaining.'"[68]

The most important passage in Crédé's little pamphlet of 64 pp. is the following, which occurs on page 4: "In October, 1879, I made the first experiment with prophylactic instillations into the eyes of the newly born, immediately after birth, using a solution of borax (1:60), because I regarded this substance as the mildest and least corrosive. At first I made this application only in the eyes of the children of sick mothers, whose vaginas had been irrigated by the above-mentioned methods during the entire birth. Even this method, however, did not lead to the desired goal, so that I took, beginning in December, 1879, instead of the solutions of borax, those of silver nitrate (argentum nitricum) (1:40), which were syringed into the eyes soon after birth. Before the injections the eyes were carefully washed externally with a weak solution of salicylic acid. The children of diseased mothers, when treated in this fashion, remained without infection, while other children who (as well as their mothers) were not treated prophylactically (because we had not believed that the mothers were diseased) did become infected, two of them rather severely."

Among the many discoveries of prophylactic value in this century we must not omit to mention (though we have no room to discuss) the multitudes of measures which have been adopted for the prevention of short-sight in particular, and of bad-sight in general. (See **Conservation of vision, Wood alcohol, Legal relations of ophthalmology.**)

The introduction of *diphtheria antitoxin* by von Behring, about 1894 (he had discovered the substance in 1890), has provided not only an efficient means of treatment for *diphtheria conjunctivæ*, but also an excellent preventive measure against both this affection and the various pareses and paralyses of ocular muscles which not infrequently result when the disease in question is permitted to invade the general system and to develop therein.

The use of *salvarsan* for syphilis, introduced by von Ehrlich in 1909,

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[67] Carl F. S. Crédé, "*Die Verhütung der Augentzündung der Neugeborenen (Ophthalmoblennorrhoea Neonatorum) der Häufigsten und Wichtigsten Ursache der Blindheit*" (Verlag von August Hirschwald, Berlin, 1884), p. 1.

[68] *Loc. cit.*

has also proved of incalculable value in the prevention of numerous syphilitic affections of the eye.

Treatment.—Very soon after the appearance of Scarpa's book in 1801 *the treatment of iritis by means of mydriatics* was introduced by Johann Adam Schmidt (in 1805). (The use of mydriatics as an aid to diagnosis, which came in very much earlier, has already been adverted to.) Schmidt, that is to say, in an article, "Der Erste Gelungene Versuch, den Ueberwiegenden Expansions-Trieb der Iris bei Anfangener Iritis durch Erregung des Contractions-triebes zu Beschränken" (*Oph. Bibl.* III, 1, 178) described a case of iritis which had followed a cataract extraction, and which he had cured completely in a week by means of the instillation of the extract of hyoscyamus. The earliest use (in 1809) of a mydriatic in an idiopathic affection of the eye was made by John Cunningham Saunders (the founder of Moorfields) and by him recorded in the second chapter of his text-book. The remedy in this case, however, was not hyoscyamus, but belladonna. Shortly after this, the employment of mydriatics in iritis became general.

Atropin was isolated in 1831, by Mein, and was shortly afterward employed in the treatment of the eye (for iritis) by Oehler.

The treatment of pannus by blennorrhagic inoculation was practised and reported by Jaeger in 1812; and, in 1882, de Wecker, of Paris, introduced to European ophthalmology the use of an *extract of jequirity* for the same affection. Jequirity had, however, long been in use in Brazil prior to 1882.

Electricity in ophthalmology began to be employed about the middle of the century. *Electrolytic epilation* was first employed by Charles Eugene Michel, of St. Louis, in 1869. The needle was of platinum, 3/8 of an inch in length and as thick as a sewing needle, No. 8. A number of later methods were also invented by Michel, including the one in common use today. (Of these we shall speak at length in the fifth division of this article, America.) *Galvano-cautery* in ophthalmology is the gift of Legroux, chief of the clinic for Gillet de Grandmont (in 1879). Legroux employed this form of treatment especially for phlyctenular conjunctivitis and keratitis. Neiden, however, in 1884, reported a series of cases, embracing a number of affections, in various stages of development and with numerous complications. The electric ophthalmoscope has been already described, under *Diagnosis.*

Of late the non-electric thermo-cautery has been considerably revised, especially by Prince, whose "*corneal cautery without contact,*" otherwise known as "*Pasteurization,*" is a valuable contribution to

ophthalmic therapy.[69] An egg-shaped copper ball, affixed to a stem, is heated and tested by a thermometer to see that the temperature does not exceed 150°. Then the ball is held 3/16 of an inch from the ulcer. The progress of the infection is nearly always stopped, and yet but little, if any, injury is done by the heat to the non-infected tissues.

Subconjunctival injections were introduced by Rothmund in 1866. He, however, employed these excellent procedures only for the removal of corneal opacities. Darier, in 1893, reported the use of such injections with very great success in a large variety of ocular infections. Mellinger's experiments, reported in 1896, contributed further to our knowledge of the subject, and T. A. Woodruff, in 1909, introduced the valued formula of which the active principles are iodine and iodide of potassium.

We have already seen, when discussing the ophthalmology of antiquity, that the lodestone and its iron-attracting and -repelling properties, were very well known to the ancient Egyptians and Greeks, but that none of the ancient peoples employed this substance in the treatment of the eye, except as a casual ingredient in eye-salves. We also saw that the ancient Hindus (as recorded by Susruta *circa* the beginning of the Christian era), made use of the magnet for the purpose of extracting foreign attractable substances which had entered the body *via* a wound in the skin, but that these people, as far as we know, had never employed *the magnet in ophthalmology.*

Then (as we also saw) for about a millenary and a half, there was not the slightest progress in the use of the magnet medically. The long period of torpor, however, was at last broken into by Braunschwyck, who, for the very first time in history, removed a foreign body from the eye by means of a magnet. The date of the record of this fact is 1462 (in Braunschwyck's book, "*Dis ist das Buch der Cirurgia,*" etc.).

Braunschwyck's performance was repeated by Fabricius Hildanus (or Wilhelm Fabry) in 1624.

Then came again a very long period of neglect which was only broken up by Nikolaus Meyer (in 1842), who first removed a foreign body magnetically from the interior of the eye—that is to say, by way of a previously existing (accidental) perforation in the sclera.

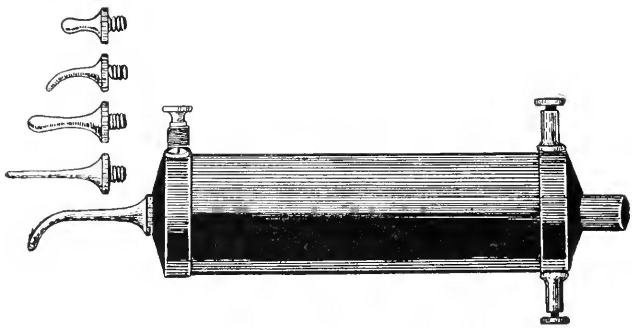
The first to make a surgical incision through the ocular tunics for the purpose of performing the magnet-operation was Dixon, of Lon-

[69] The actual, but of course non-electric, cautery *with* contact was frequently employed by Scarpa, as we saw in the abstract of his text-book (1801). This form of cautery was also in use in ophthalmology throughout the middle ages and antiquity.

don, who, in 1859, removed in this manner, by means of a permanent magnet, a piece of the blade of a pair of scissors.

McKeown, of Belfast, Ireland, in 1874, was the first to introduce the tip of the magnet into the vitreous.

Julius Hirschberg, of Berlin, in 1875, invented *the electro-magnet for the removal of attractable substances from the eye*, and since that



Hirschberg's Magnet.

time a number of special magnets have been introduced, as follows: Gruening, in 1880; Snell, in 1881; Bradford, in 1881; Hubbell, in 1884; Haab (the "giant" magnet), in 1892, and Sulzer (the "horseshoe" magnet), in 1894. Numerous other magnets and their special values, actual or supposed, are duly set forth in the non-historic portions of this work.

The use of antitoxin has, of course, been of excellent service in ophthalmic therapy (as well as prophylaxis, already adverted to) if not of the same importance as in rhinology and laryngology. It was introduced, as I have said, by von Behring in 1894, though discovered by him in 1890.

More drugs were probably introduced in ophthalmology (as well as in general medicine) in the course of the 19th century than in all the other centuries combined. Of these we have noted a number, together with their histories, in a footnote to "artificial mydriasis" when speaking of *diagnosis*, and will mention more hereafter under *surgery*.

Refraction.—To record the history of this enormous subject through the course of the 19th century would call for a very much larger amount of space than is given to the whole of this article. Moreover the matter has more than merely been adverted to already in "**Eye-glasses and Spectacles, History of,**" as well "**Ophthalmic Lenses and Prisms.**" We may, however, for the sake of a clear connection, add

that astigmatism was first discovered by Thomas Young in 1801, and first corrected by another Englishman, George Airy, in 1827. Two years later the McAllisters, opticians of Philadelphia, were making cylindrical lenses and had them on the market. Still, the development of refractional correction was very, very slow,[70] until the discovery of the ophthalmoscope—that great magician's wand of ophthalmology—when, suddenly, all the slowly accumulated humus of the optics of by-gone centuries sprouted up into life, and began to blossom and bear fruit. The theories of Euclid and Alhazen, the discovery of the effect upon the eye of convex lenses by Roger Bacon, the work of the Spanish notary, Daça da Valdes; the wide-ranging investigations of optical principles generally, by Johann Kepler: all these matters and many another began to prove of value either directly or indirectly, as soon as the ophthalmoscope had been described. The first to use this instrument for the estimation of refractional errors was Ed. von Jaeger, son of the better known Friedrich von Jaeger and grandson of G. J. Beer. The date of this important contribution to our art is 1855 ("Ergebnisse der Untersuchung des Menschlichen Auges mit dem Augenspiegel," *Sitzungsbericht d. k. Akad. d. Wissensch. Math.*, Vienna). Skiascopy was introduced by Sir William Bowman, of London, for the detection of irregular astigmatism and conical cornea (*Oph. Hosp. Rep.* II, p. 157, Oct., 1859). Bowman was also the first (in 1864 or earlier) to apply skiascopy to the detection of astigmatism generally—a fact recorded by Donders in his "*The Refraction and Accommodation of the Eye*" (1864). Cuignet, of Lille, France, in 1875, explained the use of the ophthalmoscope not merely for the detection of astigmatism, but for the detection and even the measurement, of every form of ametropia. Cuignet called the procedure "keratoscopy." Parent, a later student of the art, substituted "retinoscopy," while Priestley Smith, in 1884, suggested the name of "shadow test." The term in commonest use today, "skiascopy," was suggested by Egger.

The "indirect method" of ophthalmoscopy was invented in 1852 by Ruete (*D. Augenspiegel u. d. Optometer*, Göttingen). Ruete employed a concave perforated mirror, held at a considerable distance

[70] We should not, of course, forget the first trial-case, that of Fronmüller, already mentioned in the present article, and described in *Jour. d. Chir. u. Augenh.*, II, 1843, p. 175, in a communication entitled "Ueber die Auswahl der Brillengläser"—a communication which is reproduced (translated into English) in the Appendix to this *Encyclopedia*. See **Fronmüller.** Nor should we neglect the various test-types (the first being those of Küchler) dating the same year as the trial-case—1843—already described in the 19th century section of the present article, under *Anatomy and Physiology*.

from the observed eye, and between the mirror and the eye one (sometimes two) spherical convex lenses.

The earliest attempt to measure the curvature of the eye in general and of the cornea in particular (ophthalmometry) was made by Thomas Young, who employed no other instruments for that purpose than a pair of blunt dividers. The earliest ophthalmometer was that of Helmholtz. This was invented in 1854, and described in Graefe's *Archiv*, in a paper entitled "Ueber die Accommodation des Auges." This instrument was really a modification of a pre-existing heliometer. The original ophthalmometer of Javal and Schiötz was introduced in 1882, but since that time has undergone innumerable modifications.

Two "Bibles" of refraction appeared soon after the invention of the ophthalmoscope. The first of these was the "*Textbook of Physiological Optics*" by Helmholtz (Part I, 1856; Part II, 1860; Part III, 1867). The other was Donders' "*The Refraction and Accommodation of the Eye*" (1864). It will be observed that Donders' work appeared while that of the older man was still in process of appearance. To describe these works would be superfluous here.

And now we need but to add that it was chiefly by the labors of Arlt that the medical profession was induced to assume, as a portion of its duties, the correction of errors of refraction. Before Arlt's day this division of our service lay almost exclusively in the hands of incompetent men—as in fact it does to a certain extent at the present time.[71]

And so we have come to an end of "refraction," the treatment of which subject, because of a lack of space within this article, has been but little more than a list of discoveries and dates. The case is somewhat better in the matter of 19th century

Surgery.

Already, when speaking of Daviel, we finished, as a matter of convenience, the discussion of the cataract operation throughout its numerous modifications until the present day. We are therefore, now,

[71] Refraction has nevertheless become an extremely familiar subject (by reason of numerous articles in magazines, weeklies, and newspapers, as well as of lectures in the public schools), not only to ophthalmologists but also to the educated portion of the laity. Thus, Cardinal Newman (for a single example) a good many years ago: "To a short-sighted person, colors run together and intermix, outlines disappear, blues, reds and yellows become russets and browns, the lamps or candles of an illumination spread into an unmeaning glare, or dissolve into a milky way. He takes up an eye-glass, and the mist clears up; every image stands out distinct, and the rays of light fall back upon their centers."

Some day the subject of refractional errors will be actually and positively understood and appreciated even by members of the general medical profession.

free to direct our attention to the lesser ophthalmic surgery of the 19th century, as well as to review, by way of prelimination and with the very greatest brevity, the more general subjects of *asepsis*, *antisepsis* and *anesthesia*, as these important surgical auxiliaries have come to be applied and developed in ophthalmology.

Very soon after the introduction of antisepsis and asepsis into general surgery (a matter already discussed herein) these means of securing a germ-free operation were taken up in ophthalmology. The man who introduced them in our special field was Alfred (not to be confounded with Albrecht von) Graefe. Lister's ideas, as a matter of course, required much modification before they could be of use in ophthalmology, and the most of the modifications we owe to Graefe. Suppuration after cataract operations at once became a thing of the past, or at least of very rare occurrence. (The treatment of many diseases and injuries of the eye by antiseptic substances—boric acid, carbolic acid, corrosive sublimate, menthol, thymol, eucalyptol, etc., *ad infinitum*—came in simultaneously with germ-free surgical operations, as the merest matter of course!) An English translation of the whole of Alfred Graefe's article (Die Antiseptische Wundbehandlung bei Cataract Extractionen, *Archiv f. Ophthalmologie*, Band XXIV, Abt. 1, pp. 233-251) will be found in the Appendix to this *Encyclopedia*, under the caption, **Graefe, Alfred.**

Anesthesia (general, in the beginning) began, as we have seen, in 1846. The first to employ a general anesthetic for an ophthalmic operation was, so far as I have been able to ascertain, F. H. Brett, M. D., F. R. C. S. E., who, in "*The Lancet*," Vol. I, 1847, at p. 80, published an account of three ophthalmic cases in which he had operated under ether anesthesia. This account will be reproduced in full, in the Appendix to this *Encyclopedia*, under the heading, **Brett, F. H.**

The first to perform an ophthalmic operation under chloroform was Johann Christian Jüngken (*Ueber die Anwendung des Chloroforms bei Augenoperationen.* Ein Sendschreiben von Dr. J. C. Jüngken, Berlin, 1850). In the preface to this little work, its author declares that "about a year and a half ago a young girl, perhaps twenty years of age," had been sent to him, blind from double-sided cataract. Each eye had already been operated on three times, and without success. Just as Jüngken was on the very point of beginning to perform yet another operation—i. e., for the extraction of thickened capsule, "the patient began to cry loudly, and broke out into these words: 'Ach! great God! I am truly unfortunate, for I have already been operated on three times, and now the only hope which remains to me is to be

put to the test. Can you not, therefore, etherize me,[72] so that, at least, I may not feel the operation?' I at once refrained from operating, and had chloroform administered—whose effects became apparent very promptly. . . .

"The thought that one is about to have his eyes operated on, contains for every person, whatsoever his education may have been, something truly shocking. An ignorant person dreads the pain, howsoever much he may be assured that the operation is painless, while an educated person sees before him all the consequences, which the important act, now on the point of deciding his future destiny, may entail upon him. The number is not small of those who, because of fright about an operation, prefer to pass their lives in blindness. For all it is truly a beneficence, to be able to sleep away their fears and cares, and then to awaken in the possession of sight. It seems to belong to a world of fable, when one can say truly to the blind that, in the course of a gentle sleep, he will get his sight again, and yet, nevertheless, this is actual fact."

The years have dulled, perhaps, our own appreciation of anesthesia.

Cocain, the local effect of which on the nose and throat had been discovered by von Anrep, was introduced by Koller as an ocular anesthetic in 1884. (See in Appendix, **Koller,** beneath which head a complete translation is given of Koller's original article on his great discovery.)

For infiltration anesthesia we are indebted to Schleich (*Ueber Schmerzlose Operationen*, Berlin, 1889), and for the introduction of this anesthetic method in American ophthalmology to Harry V. Würdemann (*J. A. M. A.*, Oct. 29, 1904, and Nov. 16, 1905).[73]

To trace the development of local anesthesia in eye surgery would be to trespass on the non-historic portions of this work. We may, however, say, in brief, that the various substitutes for cocain were introduced as follows: Holocain, by Hirschberg,[74] in 1897; eucain and beta eucain, by Schering, in 1896; alypin, by Impens, in 1905; novocain, least poisonous of all, by Braun, in 1905; and euprein, most powerful by far in the list of ocular anesthetics, by Unger, in 1913.

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[72] It is interesting to note that what this German girl actually said was "etherize." "Können Sie mich denn nicht aethern?" A knowledge of ether and its surgical uses, had, most obviously, penetrated, in 1848, from the United States (not merely indeed to the German profession, but) to the German laity. It is also interesting to know that the "young girl of perhaps twenty years" got back her sight as a result of the operation in question.

[73] See herein, **Anesthesia in ophthalmic surgery,** Vol. I, p. 443.

[74] See Hirschberg, "Ueber die Anwendung von Salzsaurem, p-Diäthoxyäthenyldiphenylamidin als Ersatz für Kokain" (*Central-blatt f. Prak. Augenheilk.*, Jan., 1897).

In connection with ocular anesthetics we think, of course, of the very important substance, adrenalin, whereby not only have numerous ophthalmic operations been rendered bloodless, but also the various ocular anesthesias have been considerably intensified and greatly prolonged. The history of this remarkable substance (the blood-pressure raising principle of the suprarenal gland) is, in brief, as follows: Abel, in 1897, announced the discovery of a body which he called "epinephrin," but which, as it seems, was not an actual isolation of the pressure-raising principle. Then, in 1900, a Japanese professor, Jokichi Takamine (at the time employed in the chemical and pharmaceutical laboratories of Parke Davis & Co., Detroit) succeeded in effecting an absolute isolation of the principle in question. This principle was called by him, "adrenalin."[75]

Now, with the surgical preliminaries—anesthesia and asepsis—disposed of, we are ready to consider the ophthalmic surgery proper of the 19th century. This we will do beneath the following sub-headings:

1. Lid Operations.
2. Operations on the Conjunctiva and Cornea.
3. The Surgery of the Lachrymal Apparatus.
4. Strabismus Operations.
5. The Various Operations for the Relief of Glaucoma, or of the Pain Proceeding from that Disease.

Of each of these classes of operations in its order.

Lid operations.—In our brief review of Scarpa's book, published at the threshold of the century, we saw that operations on the lids consisted entirely and exclusively in the almost unmodified procedures of the ancients for ectropion and entropion. That is to say, for the former affection, Scarpa destroyed "the superficial fungus of the internal membrane of the eye-lid," with silver nitrate or removed it with scissors, while, for the inward curving of the lid, he simply excised a fold of skin down close to the ciliary border. The division of cicatrices which have resulted in ectropion, is a measure which Scarpa mentions indeed, but only to condemn it, "as it does not produce a permanent elongation."

Eyelid surgery, then, is a product of the 19th century almost exclusively.

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[75] Other attempts to isolate this principle had been made, not only by Professor Abel, of Johns Hopkins, but also by Dr. B. Moore, of London University, and Dr. O. V. Furth (who called his product suprarenin) of the Physiological Chemical Institute of Strassburg. There has been some acrimonious controversy regarding the question of priority in this matter—a subject into which we cannot enter here, further than to say that the priority for adrenalin has been assigned to Professor Takamine by the U. S. Patent Office.

In considering the blepharotic surgery of this period, we shall have to divide our subject into canthoplasty, tarsorrhaphy (or blepharorrhaphy) and the various operations for ptosis, trichiasis, entropion and ectropion, as well as, finally, blepharoplasty in the narrow sense—i. e., the various procedures for the restoration of a lid.

Canthoplasty, or the enlargement of the palpebral fissure by means of an operation at the outer canthus of the eye, was invented by von Ammon in 1839. Von Ammon divided the canthus horizontally with the scissors (provisional, or temporary, canthoplasty) and then, if the enlargement of the palpebral opening was designed to be rendered permanent, the sides of the conjunctival wound were sutured to the sides of the wound in the skin.

A modification of the provisional canthoplasty was introduced by von Stellwag in 1862. It consisted in making the incision not quite horizontal, but downward and outward, and was called by its inventor "oblique blepharotomy or sphincterotomy."

One of the best of the numerous canthoplasties, or cantholyses, is that of C. R. Agnew, of New York, invented in 1875. It consists, as nearly everybody knows, in making the incision in the skin very much longer than that in the conjunctiva, dividing the external canthal ligament, and then in suturing the conjunctival angle not to the angle in the skin, *but* to the upper margin of the skin-incision, "as far as it will go without stretching." To Agnew must also be given the credit of first directing the attention of the profession to the very great value of canthoplasty as a means of combating conjunctival and corneal inflammations.

Tarsorrhaphy, or the surgical procedure whereby the palpebral fissure is shortened by uniting the edges of the lids (the very opposite, therefore, of canthoplasty) was originated by von Walther in 1826. It consists, as is known, in paring the upper and lower borders of the lids throughout a sufficient area, and then uniting them by sutures.

Von Walther's tarsorrhaphy was external, i. e., performed at the outer canthus. Median tarsorrhaphy, or closure of the fissure at the inner, or nasal, angle—a procedure not so much in use as that devised by von Walther, was originated by von Arlt in 1874.

For *ptosis* the number of operations which have been devised are very much fewer in number. Pagenstecher's ptosis operation (perhaps the simplest of all, and one of the very earliest) was invented in 1881 (Eine Neue Operation zur Heilung der Ptosis, *Bericht d. Internat. Congress zu London*, 1881). Everbusch's operation whereby the insertion of the levator is advanced—a much superior operation of course—was first described in "*Monatsblatt für Augenheilkunde*" in 1881, at

p. 100. Panas's operation, the so-called "flap-method," was introduced in 1886 and is described in the "*Archives d'Ophtalmologie*" for January and February of that year.

For *trichiasis* there are numerous operations, all (except the ancient method of excising a fold of skin from the lid) devised since the beginning of the 19th century. Flarer's "ablation of the zone of hair-follicles" is nowadays done but seldom (because of the disfigurement produced) and then almost exclusively on the lower lid. Its place has, of course, been taken almost entirely by the various methods of transplantation of the zone of hair-follicles. Flarer's operation was described by him in 1824, in a 98-page book entitled "*Reflessioni sulla Trichiasi*," etc., and was long of considerable use.

Georg Emanuel Jaesche, in 1844, modified the original ablation method of Flarer, by preserving the zone of hair-follicles (instead of throwing it away) and, having turned it end-for-end, transplanting it into the gap from which it had come. This procedure was modified by Arlt into the well known Jaesche-Arlt operation for trichiasis (Graefe-Saemisch *Handbuch der Gesamten Augenheilkunde*, Erste Auflage, Vol. III, p. 447).

Hotz's method, which consists in making an incision along the upper border of the tarsus, excecting some of the fibres of the orbicularis, and then of sewing the lower wound-lip to the upper tarsal border, was first described by its inventor, Ferdinand Hotz, of Chicago, in Knapp's *Archives* in 1880.

The permanent removal of the cilia by electric epilation was the invention (as already stated) of an American, Charles Michel, of St. Louis (Trichiasis and Distichiasis: With an Improved Method for Their Radical Treatment, in "*St. Louis Clinical Record*," Oct., 1875, p. 145).

Snellen's method, whereby a prismatic longitudinal piece is exsected from the tarsus, with a view to the straightening of that structure, was described by its inventor, Hermann Snellen, in an article entitled "Entropion-naad" (*Verslagen gasth. voor ooglijders*," 1860).

Other operations for trichiasis, all rather too well known to need description, are as follows: Spencer Watson's, *Oph. Hosp. Rep.*, VII, 1873, p. 440); Nicati's, (*Marseille Médicale*, 1879); Schoeler's, (*Klinische Bericht*, 1880); Dianoux's, (*Annal. d'Oc.*, 1882, p. 132); Gayet's, (*Annal. d'Oc.*, 1882, p. 27); Vossius's, (*Bericht d. Ophthal. Gesell.*, Heidelberg, 1887, p. 42); van Millingen's, (*Ophthalmic Review*, 1887, p. 309).

The operations for entropion have (excepting the ancient procedure of excising a fold of skin, and the Arabic skin cauterization) all been

devised since the time of Scarpa's textbook, and their name is surely "legion." The earliest of any importance was probably the Gaillard suture,[76] or sutures, (*Bulletins de la Soc. Méd. de Poictiers,* 1844). Close to the border of the lid at the junction of the outer and middle thirds thereof, the needle, armed with a suture, was entered, and, being shoved well under the fibres of the orbicularis, was made to emerge from the tissues at a point somewhat below the inferior conjunctival cul-de-sac. A similar suture was placed at the junction of the middle and inner thirds. The sutures were then tied tight, and allowed to cut their way out. The resulting scars, though very disfiguring, were frequently productive of much relief.

This operation of Gaillard was modified by Arlt (Graefe-Saemisch *Handbuch der Gesamten Augenheilkunde,* Vol. III, p. 457, 1874) in the following manner: A thread is armed with a needle at each end. One of the needles is entered close to the border of the lower lid, at the junction of the middle and inner thirds thereof, and caused to emerge upon the cheek at a point a little lower than the inferior conjunctival cul-de-sac. The second needle is passed in similar fashion so that a very short loop of thread is seen, outside the skin, below the lid-border. A roll of adhesive plaster is slipped beneath this loop and the ends of the suture are tied across another. Then a similar double-suture is placed at the junction of the middle and outer thirds of the lid, and the operation is complete. It is only used today for temporary entropion, such, for example, as forms beneath a bandage.

Meanwhile, Snellen's suture had been devised. (*Congrés Internat. d'Ophtalmologie,* Paris, 1862, p. 236.) This also was a doubly-armed suture. One needle was entered from the lower conjunctival cul-de-sac and passed straight out to the skin. It was then re-entered at the point of exit, passed upward underneath the skin to nearly the lid border, and again brought out through the skin. The second needle was passed in similar fashion, but about three mm. external or internal to the first. Two or three such double sutures were generally applied. The great superiority of this operation over that of the Gaillard method, either modified or unmodified, is apparent to all who have tried them.

Gillet de Grandmont, however, improved the method of Snellen. (*Bull. de la Soc. d'Ophtalmologie de Paris,* I, 1889). He, that is to say, passed his needles from the conjunctival cul-de-sac to the border of the lid, without any intervening exit from the skin.

Green's operation (*Trans. Am. Opht. Soc.,* Vol. III, p. 167, 1880) is one of the very best, and, though devised by an American, John Green,

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[76] Wardrop was the first to *suggest* the employment of sutures for the amelioration of entropion.

Sr., of St. Louis, is here included for the sake of a better continuity in the present section of this article. In this operation, as is very well known, an incision is made through the tarsus from the conjunctival surface, about 2 mm. from the lid-border, and extending from the inner to the outer canthus. A strip of skin is next excised, 2 mm. wide, whose lower border runs parallel with the eyelashes and about $1\frac{1}{2}$ mm. above them. Fine silk sutures are introduced as follows: The needle, in each instance, is inserted into the lid-margin just behind the cilia, caused to appear in the wound whence the strip of skin was taken, then entered again at the upper margin of the wound, carried close to the anterior surface of the tarsus and caused to emerge two-fifths of an inch above. The sutures being tied, the margin of the lid is strongly everted, and the wound in the conjunctival surface of the tarsus, gaping widely, fills with granulations, and a permanent cure is the result.

The Green operation marks, no doubt, the acme of development in entropion operations.

Boeckmann's sutures, however. are also useful. (*Norsk Magazin f. Laegevidinsk*, Vol. XI, 1880) as are also those of Allport (*Am. Jour. of Oph.*, 1888, March, p. 78) in considerably greater degree. These are sutures passed from the conjunctival surface of the lid, through the whole thickness thereof, just above (or, in the lower lid, below) the tarsus, with a view to fixing the fibres of the orbicularis to the tarsus.[77]

An excellent and much employed operation for entropion of the lower lid is that of James Moores Ball. (*Annals of Oph.*, Jan., 1905, p. 78). A clamp having been applied, a horizontal incision is made, 2 mm. from the lid-margin, obliquely through conjunctiva and tarsus. The clamp having been reversed, an incision is made through skin and muscle as far as the lower margin of the tarsus extends. Sutures, with beads, are then so passed as to cause the lid to assume an approximately correct position.

Many of the operations for trichiasis, referred to above, under the "*trichiasis*" sudivision of this article, are, as is known, useful for entropion also, as in fact are, too. (for spastic entropion) canthotomy and the oblique sphincterotomy of Stellwag.

The operations for *ectropion* have all, like those for the counter-condition, been devised since the time of Scarpa's text-book. One of the earliest was that of Sir William Adams, of London (*Practical*

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[77] No attempt, in the present article, is made toward giving the complete technique of any operative procedure, but only so much thereof as may seem to be required *to show the development of the operative idea.* For technique in detail, see all such articles as **Blepharoplasty, Entropion, Ectropion, Ptosis**, etc.

Observations on Ectropion, or Eversion of the Eyelids, with the Description of a New Operation for the Cure of that Disease, London, 1812). A wedge-shaped piece, involving all the layers of the lid (skin, tarsus, conjunctiva) was excised about the middle of the lid. The wound was then united by a series of fine, intermittent sutures and a hare-lip pin. The results were often excellent, yet, again, the wound would not unite throughout its whole extent, or else would heal with a rough, irregular cicatrix which irritated the eyeball and also presented considerable external deformity.

To avoid these bad results the operation of von Ammon was devised (*Zeitschrift f. Augenheilkunde*, Bd. I, s. 529). By this procedure, as is very well known, the piece is not removed from the middle of the lid, but from its outer third, sometimes up close to the external canthus. A very much smoother and more certain result is secured in this way.

A further great improvement in the surgical treatment of ectropion was made by A. von Graefe (Bemerkungen zur Operation des Entropiums und Ectropions, *Archiv f. Ophthal.*, X, 2, pp. 221-232, 1864). This procedure was, and still is, of very great value when the whole of the lower lid is involved. The margin is split through its whole length, and, from the extremities of the incision, two perpendicular cuts are made, downward for 8 or 10 lines, and the procedure completed in the manner which the reader will readily recall.

Richet's operation was invented in 1873 (*Recueil d'Ophtalmologie*). Its especial value, as the reader will remember, lies in cases of ectropion of the lower lid produced by adherent cicatrices at the outer margin of the orbit.

Another decided addition to the surgery of ectropion was made by Fukala (*Annales d'Oculistique*, Jan., 1894, p. 43). By this man's operation, the cartilage is depressed, while the skin and orbicularis are raised. The especial value is for cases arising from blepharitis.

What is properly called by Dr. Casey A. Wood "a new principle in ectropion operations" was first described by Dr. A. E. Davis (*J. A. M. A.*, Nov. 18, 1911). It consists, essentially, in shortening the tarsus at its outer end, and then attaching it to the temporal border of the orbit. This procedure, however, being, as yet, little known, requires a full description, which is to be found in Vol. VI of this *Encyclopedia* at pp. 4141-42.

Blepharoplasty.—Blepharoplasty in the narrow sense (i. e., the various procedures for the restoration of an eyelid) is simply an offshoot from plastic surgery in general. Now plastic surgery in general began in ancient India with the restoration of the nose—a procedure

which was often called for in that country because of the very common punishment (of adultery in particular) by abscission of the organ in question. Little, however, if anything, was done in European countries in the way of plastic surgery till about the beginning of the 15th century, when the Hindu rhinoplastic operation (whereby the flap from which the nose was made was taken from the cheek) began to be practised as a secret art by a surgeon called Branca, who lived at Catania, in Sicily. What is known as the Italian method (that whereby the flap is taken from the arm) was the invention of Branca's son, Antonio. In the 16th century, the Italian method was practised very extensively by Gaspar Tagliacotti, a surgeon of Bologna, who, on this account, was widely celebrated.

In the 17th and 18th centuries, rhinoplasty seems to have fallen almost completely out of use. About the beginning, however, of the 19th century, the Indian method of rhinoplasty was revived, in 1814, in London, by Carpue, and, two years later, the Italian method by C. F. von Graefe, of Berlin.

Blepharoplasty was the invention of another Berliner, Johann Friedrich Dieffenbach, who had already practised the restoration of the nose by the Indian method—i. e., by the method whereby a pedicled flap is taken from the neighboring cheek. It was only a step to the origination of the so-called Dieffenbach's blepharoplasty, which is still in use and by which a triangular piece of skin is excised from the (lower) lid, thus taking away the offending scar, or hiatus in the lid, the gap being covered by a pedicled flap from the adjacent portion of the cheek. The date of publication of this operation is 1835.

Blepharoplasty by the Italian method was first proposed by J. Sichel, but was first performed by Berger, another Frenchman, in 1879.

Skin-grafting (by mosaic-particles of epidermis) was originated by Réverdin in 1871; but was much improved by the method of Thiersch, which consisted in the transplantation of strips of considerable extent, including not merely the epidermis, but the outer portion of the dermis as well. Both these methods were rendered possible by the prior introduction of Listerism.

Blasius's blepharoplasty was introduced in 1842, Graefe's in 1858, and Businelli's in 1879. Snydacker's method (transplantation of a pedicled cervical flap) was introduced by Snydacker of Chicago, in 1905, and modified by Morax, of Paris, just a little later. All these methods are fully described in the scientific portions of this work.

Operations on the conjunctiva and cornea.—One of the earliest operations for *symblepharon* was that of Friedrich August von Ammon, devised in 1834. By this method the lid is placed upon the stretch and

the band uniting the lid with the ball is divided close to the lid (not the ball) and then the band is sewn down into the commissure, so that the wound on the ball is covered, while that on the lid is left raw.

Dieffenbach, about the same time, practised division of the offending band together with a folding backwards of the lid into the conjunctival cul-de-sac, so that the skin was placed in contact with the bulbus till healing had been completed.

Teale's operation, introduced in 1861, consisted in severing the body of the band along the margin of the cornea, leaving the corneal portion to atrophy in time.

Knapp's well known method—i. e., the covering of the defects "with vertical, stretched flaps, stitched into the lower fornix"—was first described by its inventor in Graefe's *Archiv f. Ophthalmologie,* XIV, 1, 1868, s. 270. This method is still a favorite.

A decided improvement in the surgery of symblepharon was introduced in 1874 by von Arlt (Operationslehre, Graefe-Saemisch *Handbuch der Gesamten Augenheilkunde*, Bd. III, 1874, p. 439). The essential idea in this method is that the flap of connecting tissue goes over to the lid, and not the ball, the apex of the flap being sewn down into the commissure by a doubly-armed suture, the ends of which come out upon the skin, where they are tied on a roll of adhesive plaster.

Von Arlt's procedure is perhaps the one most often employed today. Adolf Alt's, however, is also, and properly, a favorite, especially in cases where the adhesion is broad, dense, and encroaching on the cornea. It consists, essentially, as everybody knows, in the making of two diverging flaps, and was first described in the *Archives of Ophthalmology*, IX, p. 293, 1880.

The grafting methods of Réverdin and Thiersch (described and dated in other connections in this article) were early applied in the treatment of symblepharon. The transplantation of rabbit conjunctiva was first recorded by Wolfe, of Glasgow, in 1872, while Stellwag, in the following year, employed the mucous membrane of the mouth and vagina.

The *pterygium* operation presents an almost infinite variety. An early procedure was that of Acrel (Richter's *Chirurgie*, Göttingen, 1771, s. 97) whereby the head was circumcized and the body ablated totally.

The method of Arlt, which is still in use, was proposed in 1850 (Arlt, *Die Krankheiten des Auges*, I, s. 164). By this procedure the neck is lifted from the globe with forceps, and then transfixed with a linear Graefe knife. By a sawing movement the head is severed from the cornea. The rest of the growth is then cut out with scissors.

Coccius, in 1854, advised that the resulting bulbar defect be closed, at least in part, with sutures.

The method of transplantation was introduced by Desmarres (*Traité Théorique et Pratique des Maladies des Yeux*, 2d ed., 1855). The tip of the growth was sewn down into a pocket, as still is done.

Knapp's operation, the double transplantation followed by conjunctival flaps, which still is a favorite, was first described in 1868, and that of Webster Fox, another well known transplantation method, in 1904.

The surgery of the lachrymal apparatus.—This department of the surgery of the eye was little developed in antiquity. The reader no doubt remembers the most of what we have said upon this subject, but a brief review thereof may be of assistance. In ancient Babylonia (as shown by the *Code of Hammurabi*, 2250 B. C.) the method of treating "an abscess of the eye" consisted simply and solely in the opening of such an abscess with a knife. By Hippocrates (about 400 B. C.) almost nothing is said on the subject of lachrymal diseases. In the time of Celsus a lachrymal fistula was treated in three ways—by excision, by the chemical and by the actual, cautery. In the time of Galen there were once again three methods: (1) Excision of the canthus, followed by the drilling of several small holes through the bone into the nose, and then the application of caustic medicines; (2) Denudation of the bone, followed by the application thereto of the actual cautery; (3) Incision down to the bone, followed by the insertion of a metallic funnel and the pouring down onto the bone through the funnel, of molten lead. In Aëtius of Amida and Paulus of Ægina we find no further advance in lachrymal medicine or surgery, and the Arabs, in these matters, were merely repeaters of these two men. Even in the modern era there was still no manner of improvement until the time of the Frenchman, Dominique Anel.

Now Dominique Anel was a man of the 18th century, but discussion of his work was reserved till the present moment as a matter of convenience—i. e., because his contributions to the treatment of lachrymal diseases formed part and parcel of the strongly marked development of lachrymal surgery and medicine which appeared in the 19th century.

Like all great men Anel had a great forerunner, a man that made his remarkable discoveries possible. This man, in the case of Anel, was Georg Ernest Stahl, whose tiny work, "*Programm de Fistula Lacrymalis*" (1702) was the first of importance on its subject since the time of Claudius Galen. The theory which Stahl laid down was this: That the so-called "fistula lacrymalis" was not—contrary to what had been

supposed from the time of the earliest ancients to his day—owing to some affection (swelling or atrophy) of the lachrymal caruncle, but, instead, to disease of the canaliculi, the lacus lacrymalis, or the lachrymo-nasal canal, resulting in stenosis, complete or partial, of one or another of these passages. And Stahl devised a very ingenious procedure for the treatment of these affections. He, that is to say, introduced *via* the upper *punctum*, a catgut violin string into the lacus lacrymalis, made an incision through the wall of the sac obliquely, and, finally, passed into the sac tents, or plugs, of lint saturated with certain balsamic preparations. In this manner he succeeded in curing a number of cases which, otherwise, would have been incurable.

Now appeared upon the scene Anel, whose procedure, first employed on Feb. 20, 1713, was, in brief, as follows: Through the upper canaliculus was daily passed into the sac, and on down into the nose, a golden, or silver, sound, of about the thickness of a hog's bristle, and furnished at its distal end with an olive-shaped button or knob. Then, through the lower canaliculus, he injected, by means of the syringe which still bears his name, an astringent preparation into the sac, and, when possible, on down into the nose. The procedure was repeated, as stated, daily, till the fluid would run down into the nose with ease. Then, as a rule, the patient was cured.

The importance of Anel's discovery hardly needs to be emphasized. Even the instruments—the sound and the syringe—are still in use, i. e., after more than two hundred years.

The next to contribute to the advance of lachrymal surgery was Heister, who, in 1716, defined, classified, and clarified the different affections of the lachrymal drainage apparatus. According to him, the affections of these parts are four in number: epiphora, lachrymal tumor, lachrymal abscess, lachrymal fistula. All these forms (as pointed out by Hirschberg) were known to the ancients, who, however, did not so sharply differentiate them as did Heister.

The next great advances in lachrymal surgery were introduced, in 1857, by Sir William Bowman, of London, who slit the canaliculi, and then passed sounds of considerable diameter. Next to the services of Anel, these were, of course, the greatest. Before the time of Bowman, sounds had been passed either by the natural passages or through an incision in the sac-wall. Bowman pointed out the remarkable frequency with which the constricted portion of the passage is to be found at its nasal extremity, and also invented the well known Bowman's canaliculus knife.

Then Weber, in 1863, came forward with the probe-pointed knife, a decided improvement over all the older kinds of knives. To Weber

we are also indebted for the elastic lachrymal bougie and for forcible catherization.

Ablation of the lachrymal glands was introduced by Lawrence in 1866, and electrolysis of the lachrymal canal by Gorecki in 1874.

The rapid enlargement of the lachrymo-nasal canal—i. e., at a single sitting and throughout its whole extent—is an especially American invention. For this useful procedure we are indebted chiefly to Samuel Theobald, of Baltimore, who described, or at least referred to it, in 1876. Williams, of Cincinnati, and Noyes, of New York, had, somewhat earlier, and independently of each other, begun to recognize the necessity, or at least the desirability, of using thicker probes than those of Bowman, as well as longer and thicker ones than those of Weber. But to Theobald is due the credit of securing the introduction of this method, as well as its full and adequate development.

The extirpation of the lachrymal sac was practised, at least in a certain fashion, in Greco-Roman antiquity. It was, however, proposed anew in 1839 by Velpeau, and was actually performed and re-introduced to the profession by de Wecker in 1888.

Strabismus operations.—Strabismus, until the 19th century, may be said to have had no treatment. Bandaging the crossing eye had been resorted to, the use of strabismus masks, and one or two similar and equally ineffective procedures, had been employed, but nothing of the slightest value had ever been made use of, till the time of Delpech, Stromeyer, Dieffenbach, and Böhm. Delpech, that is to say, was the great forerunner of the immortal strabismus trio, because (in 1816) first of all in history, he divided the tendo Achilles for the cure of club-foot. This was the very beginning of orthopedic surgery, and out of it grew, in 1838 (so slowly do important ideas sometimes evolve) the proposal of Louis Stromeyer that for strabismus one or another of the recti muscles should be divided according to the requirements of the case. Stromeyer went so far as even to divide an internal rectus of a cadaver. Here (translated, of course) is his own account of his proceeding: "I expect a very great success from myotomy for crossing eyes, an operation which offers no difficulties for a skilful oculist. As the result of experiments on cadavers, I recommend for strabismus convergens spasticus the following procedure. The patient is had to close his healthy eye, while he turns the other out as far as possible. A fine double hook is then caught into the conjunctiva at the inner border of the ball; and this is given to a skilful assistant who, by its means, draws the eyeball strongly outward. Then the conjunctiva is lifted with a pincette and divided vertically with the point of a cataract knife, the orbit being opened next the inner aspect of the ball.

Now the ball is abduced still a little farther, so that the musculus rectus internus comes immediately into view. A fine sound is shoved under it, and the tendon then is divided with the curved scissors, or with the same knife with which the conjunctival cut was made. After the operation, cold applications and a dose of opium. The sound eye should be kept closed for a considerable time, in order that the operated eye may be able, by means of exercise, to recover its normal motility. That the divided muscle would be freed from cramp and regain its function, is, according to the results secured in the case of other muscles, by no means to be doubted, and the operation can scarcely affect the eye more injuriously than many an extirpation of a cystic tumor from the orbit, which, as is known, so seldom produces any unwished for results.''

In the following year (Oct. 26, 1839) the suggestion of Stromeyer was carried out upon the living subject by Johann Friedrich Dieffenbach, who published in the Berlin ''*Medizinische Zeitung*,'' Nov. 13, 1839, at p. 227, an account of this, the earliest, strabismus operation, in an article entitled: ''On the Cure of Congenital Strabismus by Division of the Rectus Internus Eye Muscle.

''A division of the rectus internus eye muscle, undertaken by me for convergent strabismus, has had an absolutely favorable result. Privy Councillor Juengken, who saw the patient on whom I operated, was rejoiced in no slight measure at the success of the operation. The patient was a boy aged 7 years. The eye was drawn strongly into the internal canthus, and in this way a considerable disfigurement had been produced. The operation I performed as follows: The head of the child was leaned against the breast of an assistant; while another assistant with a hook lifted the upper eyelid, and, with a second, drew down the lower, so that the palpebral fissure was very much enlarged. Thereupon I passed a third hook through the conjunctiva in the *internal* canthus and to a considerable depth through the cellular tissue beneath it; this hook I handed over to a third assistant. Then I fastened a fine double hook into the sclerotic at the inner canthus, which I held with the left hand, and drew the bulbus strongly outward. Then I incised the conjunctiva close to the bulbus, where it continued itself into the internal canthus, and dissected, pressing more deeply, the cellular tissue from the eye, after which I divided the muscle, with a fine pair of eye scissors, close to the ball. The ball flew, as if struck by an electric shock (being suddenly drawn outward by the rectus externus eye muscle, and then at once took up a straight position, so that, in the position of the two eyes, there was no longer any difference.

"The hemorrhage in this operation was insignificant; and yet of a sufficient amount to constitute some hindrance. The after-treatment consisted of cold applications; inflammation of the eyeball did not set in, and within 8 days the cure was complete.—To Dr. Böhm I render thanks for the very great care which he gave to the boy after the operation.

"Stromeyer, in his excellent article on subcutaneous orthopedia, speaks for the possibility of a division of the internal rectus eye muscle as a remedy for strabismus, because of experiments made by him on the cadaver. On the living, however, this operation, until now, has never been performed."

To the "Dr. Böhm" of the second paragraph above, was reserved the honor of substituting tenotomy for myotomy, as a cure for strabismus—almost as great a service to the human race as the original procedure of Stromeyer and Dieffenbach, for, after the best performed myotomy, the operated eye will almost always, after the lapse of a considerable time, swing far in the opposite direction, so that the second condition of the patient is nearly as bad as was the first. Guérin, Bonnet, and even Dieffenbach had performed tenotomies as well as division of the belly of the muscle, but Ludwig Böhm it was who *urged the importance* of cutting the tendon as closely as possible to the sclerotic.

Advancement as a cure for an eye whose internal rectus had been set too far back, thus producing what was called "secondary divergence," was first described by Jules Guérin, Nov. 22, 1841, in a paper which he read before the French Academy of Science. Guérin's procedure, however, was impractical and somewhat dangerous, inasmuch as it once or twice was followed by suppuration of the cornea. The first safe, neat and practical advancement operation was that of George Critchett, described to the Heidelberg Congress in 1862.

The later developments of the cross-eye operation are given with sufficient fulness under the separate article, **Strabismus.**

Operations for glaucoma or for glaucomatous pain.—The history of glaucoma pathology has been already considered with sufficient fulness, and we have also stated that von Graefe, having found that partial staphylomas of the cornea would recede after an iridectomy (because, presumably, of a reduction in the intraocular tension) decided to try this operation for glaucoma, the essential condition of which would seem to consist in a decided increase in the tension of the fluids within the eyeball.

Graefe first performed this operation in 1855, and first described it

in print[78] under the title, "Ueber die Iridectomie bei Glaucom und über den Glaucomatösen Process," in his own "*Archiv für Ophthalmologie.*" III, 2, p. 456, in 1857. The result, in a word, is this: that acute glaucoma is almost always curable, that the chronic inflammatory form is at times completely curable, at others not, while glaucoma simplex is, as a rule, capable of amelioration only. But what a change in the outlook for glaucoma patients, who, before this time, were condemned almost invariably to long-continued pain, and blindness, sometimes early and sometimes late, but always sure.

De Wecker, in 1867, proposed an operation which he called anterior sclerotomy, the object of which was to form a filtration cicatrix in the angle of the anterior chamber, the idea being that, when an iridectomy was performed, the relief which followed was really produced by the opening up of the spaces of Fontana rather than the taking away of a portion of the iris. This operation was first performed, in the following year, on the living subject, by Stellwag von Carion. Quaglino, Snellen, Bader and Martin, each introduced some modification of this procedure.

Irido-sclerotomy (which consists in a combination of an anterior sclerotomy with iridectomy) was first described by Panas in 1883 (*Soc. franç d'Ophtal.*) and the "combined sclerotomy" of de Wecker —sclerotomy, that is, combined with iridodialysis—(*Annal. d'Oc.*) in 1894.

The extirpation of the *ganglion supremum*, or resection of the sympathetic, was first performed by Abadie in 1900.

All of the further developments in the surgery of glaucoma are given with sufficient fulness (accompanied by enough historical matter) in the scientific portions of this work.

V.—AMERICA.

So we have finished our journey through some of the worm-holes, scientific and other, of old time, emerging at last in the sunlight of today. It has been a comparatively long and tortuous pilgrimage, and yet we have not by any means examined all the branchings of even the ophthalmologic worm-holes. That one in particular (a many-pronged and winding gallery) which is known as "comparative ophthalmology" we have hardly so much as entered, nor the very much simpler one which bears the name of "ocular hygiene." Still, we have had, I trust, a rather profitable trip, and are now about to begin another portion of our journey.

[78] He had described it to large numbers of students in 1856, for which reason that date is commonly accepted as the date of the invention—publication to the students being fully equivalent to publication in print.

Or, if the reader should happen to be a stickler for the preserving of similitudes unmixed, we are now about to witness the rising of the curtain on the fifth and final division of the ophthalmologic drama—America.

In this division of our subject, we shall find, of course, but little that is old to entertain us. America, furthermore, is a land of great clinicians, rather than of scholars and inventors (at least in ophthalmology)—a land, however, of most remarkable promise.

America was discovered, as many have heard, in 1492. Thirteen of the English colonies declared their political independence not until 1776—almost three centuries later. The present constitution was adopted in 1787, and, thereunder, we have prospered (in a few brief years) beyond the dreams of avarice. In many ways, we are now a mighty nation. Our territory has been, by steps, enlarged until it extends from ocean to ocean, from Canada to Mexico. We could place in the field, if we so desired, an army of invincibles.

But what about the greater record, the record of progress intellectual? We have invented not merely the iron-clad warship, the submarine, and the airship, but we have also devised the cotton gin, the electric telegraph and the telephone, the phonograph and the motion picture, and similar articles almost without number. Then, to come a little nearer to our special subject, behold, as it were in a vision, the vast array of general medical and surgical inventions and discoveries: The tonsillotome (by Philip Syng Physick); the first operation for hydropericardium (by John Collins Warren); the first successful operation for cleft palate (by his son, J. Nason Warren); the first successful ligature of the common iliac artery, the first exsection of the clavicle, and the first exsection of the inferior maxilla (all by Valentine Mott); the first cure of intracranial aneurysm through ligature of the carotid (by Benjamin Winslow Dudley); the first ligature of the common carotid (by Cogswell, of Hartford, Conn.); the first successful ligature of the left subclavian artery (by Philip Wright Post, of New York); the first application of a metallic ligature to a human artery (by Warren Stone); the first ovariotomy (by Ephraim McDowell); surgical anesthesia itself (by Wm. T. G. Morton); the foundation of gynecology (by J. Marion Simms); the discovery of the cause, and, thereby, the cure, of yellow fever (by Major Walter Reed, in 1901): and so on, almost *ad infinitum.*

The tale in ophthalmology, however, is a much less interesting matter.[79]

[79] Recall, nevertheless, the remark of A. A. Hubbell concerning the wholly American discovery of general anesthesia: "It will suffice to say that America

In our section on the 19th century ophthalmology of Europe, we almost wholly abandoned, because of lack of space, the personal, or biographic, aspects of ophthalmologic progress. Now, however, we shall have mere room to consider men, as well as the movements, the institutions, inventions, discoveries, and ophthalmic achievements of various other sorts. And when we shall have made an end of considering men and their individual achievements (in chronologic fashion) we shall turn our attention to American ophthalmic hospitals and societies—the results (for the most part) of combined, or associated, endeavors.

Benjamin Franklin, LL. D. The Inventor of Bifocal Spectacles, and the Earliest Figure in American Ophthalmology.

The earliest man in America to contribute to the progress of ophthalmology, was no less a personage than Benjamin Franklin,[80] the inventor of bifocal spectacles.

Franklin was born at Boston, colony of Massachusetts Bay, Jan. 17, 1706, and spent in school only four years all told. He passed the most of his life in Philadelphia, invented musical glasses, the first successful stove, etc. His researches in the field of electricity are very well known, and also extremely important. In a letter to George Whately, Passy, Aug. 21, 1784, the following passage is found on the subject of

would have glorified herself in ophthalmology as well as in general surgery had this been her only contribution."—*Ophthalmology in America*, p. 137. Hirschberg, quoting this opinion, declares that he fully agrees with it.—*Amerikas Augenärzte im 19. Jahrhundert*, p. 47.

[80] For some strange reason, not so much as mentioned by Hubbell in his "*Development of Ophthalmology in America.*"

bifocal spectacles: "Your eyes must continue very good, since you can write so small a hand without spectacles. I cannot distinguish a letter, even of large print, but am happy in the invention of double spectacles, which serving for distant objects as well as near ones, make my eyes as useful to me as ever they were. If all the other defects and infirmities were as easily and cheaply remedied, it would be worth while for friends to live a great deal longer, but I look upon death to be as necessary to our constitution as sleep. We shall rise refreshed in the morning."

In a letter from George Whately to Franklin, London, 15 November, 1784, occurs yet another passage on this important subject: "I have spoken to Dolland about your invention of double spectacles, and, by all I can gather, they can only serve for particular eyes, not in general."

Franklin's reply to Whately, Passy, 23 May, 1785, is still more interesting, and important: "By Mr. Dolland's saying that my double spectacles can only serve particular eyes, I doubt he has not been rightly informed of their construction. I imagine it will be found pretty generally true, that the same convexity of glass, through which a man sees clearest and best at the distance proper for reading, is not the best for greater distances. I therefore had formerly two pairs of spectacles, which I shifted occasionally, as in traveling I sometimes read, and often wanted to regard the prospects. Finding this change troublesome, and not always sufficiently ready, I had the glasses cut and half of each kind associated in the same circle. By this means, as I wear my spectacles constantly, I have only to move my eyes up or down, as I want to see distinctly far or near, the proper glass being always ready. This I find more particularly convenient since my being in France, the glasses that serve me best at table to see what I eat not being the best to see the faces of those on the other side of the table who speak to me; and when one's ears are not well accustomed to the sounds of a language, a sight of the movements in the features of him that speaks helps to explain; so that I understand French better by the help of my spectacles."

It is hardly necessary to insist, in a work for ophthalmologists, on the far-reaching significance of Franklin's invention.[81]

Franklin died as the result of complications produced by a vesical calculus, April 17, 1790.

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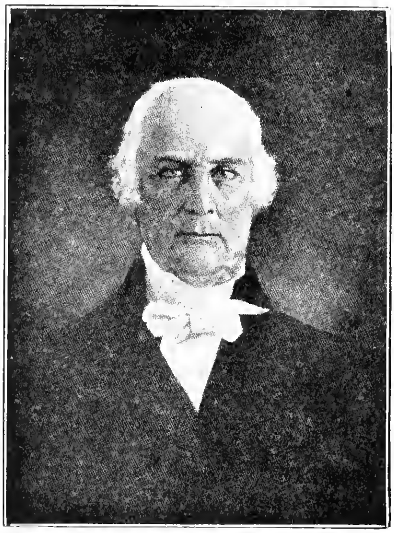
[81] For other ophthalmic passages from the works of Franklin, see, herein, **Franklin, Benjamin.**

A. The Early Group of American Ophthalmologists.

But Franklin was not an ophthalmologist, or even a physician. He was simply one of those marvelous minds which exert a powerful influence in every sphere of human thought. The first American physician of importance in ophthalmology was Elisha North, who was also the first to establish an ophthalmic hospital, or infirmary. He was born



Elisha North (1771-1843). Founder of the First Eye Infirmary in the United States.

at Goshen, Conn., Jan 8, 1771, very appropriately a son and grandson of physicians. He pursued the study of medicine for years beside his father, and, later, under a Lemuel Hopkins, at Hartford, physician and poet of considerable reputation, and yet again, with the immortal Rush. Being admitted to practice, he returned to his old home, Goshen, where he practised as general physician (though paying special attention to the eye) till 1812, when he removed to New London, Conn. There he practised till his death, Dec. 29, 1843.

The earliest eye infirmary in this country was established, as we have said, by North. This memorable event took place at New London in 1817, a rather important date for a country in which ophthalmic hospitals are at present so conspicuous and successful a feature.[82] In a book by Dr. North, called "*The Science of Life*," (1829) occurs the

[82] The earliest ophthalmic hospital in the world, it should be recalled, was that which Joseph Beer, of Vienna, opened in 1786.

following passage about this first ophthalmic hospital: "We had attended to eye patients before that time (1817), but it occurred to us then that we might multiply the number of cases of that description and hereby increase our knowledge, advertising the public in regard to an eye institution. This was done, and we succeeded, although not to our wishes in a pecuniary view of the case. Our success or exertions probably hastened in this country the establishment of larger and better eye infirmaries."

Yet another passage in the memorable work is this: "I have had the pleasure to prevent total blindness and restore sight to twelve or thirteen persons, during the last three years. These would now probably be moping about in total darkness, and be a burden to society and to themselves, had it not been for my individual exertions."

North's New London Eye Infirmary would seem to have lived for twelve or fourteen years, but the date of its death is not precisely known. May the institution be remembered.

We may add that Elisha North was also a prominent vaccinator, and author of the first book in the world on epidemic cerebrospinal meningitis. According to Dr. Walter R. Steiner (Kelly's *Cyclopedia of American Medical Biography*, first ed., Vol. II, p. 219), he was also quaintly humorous, one of the entries in his ledger, for example, running as follows: "Mr. Blank, to doctoring you until you died, $17.50."

It would seem that Elisha North should be called the "Father" of American ophthalmology. The title, however, is generally given to George Frick, of Baltimore, who published the earliest work on ophthalmology in America. He received his medical degree in 1815 at the University of Pennsylvania, and two years later was admitted to practice by becoming a licentiate of The Medical and Chirurgical Faculty of Maryland.

For a number of years he studied abroad, paying considerable attention to ophthalmology. In Vienna he became acquainted with the great Beer, by whom he seems to have been profoundly influenced throughout the remainder of his life.

In 1819 he returned to Baltimore, began to practise ophthalmology, perhaps exclusively, and seems to have had extraordinary success. Some years later, however, he became very deaf, and, in 1840, abandoned practice altogether, removing to Europe but returning to America from time to time for the purpose of visiting relatives and friends. He died in Dresden, Germany, Mar. 26, 1870.

The only book Frick ever wrote was that above referred to, entitled "*A Treatise on the Diseases of the Eye; Including the Doctrines and Practice of the Most Eminent Modern Surgeons and Particularly those*

of Prof. Beer" (Baltimore, 1823; 2d ed. with notes by Richard Welbank, London, 1826). Though based on the books of Beer, this first American work on ophthalmology contained a great deal of original matter and was written in a clear, forceful, even beautiful style. On the whole, an appropriate beginning for American ophthalmography.

It has always been a question as to whether Frick or Elkanah Williams, of Cincinnati, was the first in America to restrict his practice

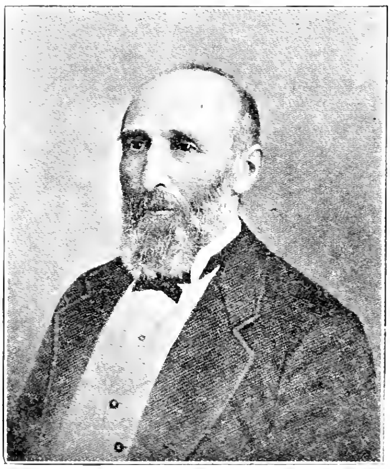
George Frick, the Father of American Ophthalmology (1793-1870).

absolutely to diseases of the eye, or eye, ear, nose and throat. To the writer it seems that Williams was the very first, although there are grounds for believing that the honor belongs to Frick.

Elkanah Williams, perhaps the first physician in America who confined his practice to ophthalmology or ophthalmology and oto-laryngology, was born in Lawrence County, Indiana, Dec. 19, 1822, the son of Isaac Williams, a captain in the U. S. Army during the War of 1812. He received the degree of A. B. from Asbury (now De Pauw) University, and that of M. D. in 1850 at the University of Louisville. He settled at Cincinnati in the spring of 1852, but, in the following November, proceeded to Europe for the study of ophthalmology. For eighteen months he worked with Desmarres, Nélaton and Roux in Paris, and

then for a number of months at Moorfields, in London. Here he received instruction from Bowman, Dixon, Wordsworth, Critchett, and others, and is said to have been for a time almost the only student in the great Moorfields hospital. He then, for a very few months, pursued his studies further at Prague, Vienna, and Berlin.

In 1855 he returned to Cincinnati, where he practised as ophthalmologist and oto-laryngologist exclusively, and was "the first regularly



Dr. Elkanah Williams (1822-1888).

accredited physician in America who confined his practice strictly to these branches." In 1860 a chair of ophthalmology was established at the Miami Medical College, and the subject of this sketch was made the first incumbent of the new position. The statement has often been made that this fact constitued Dr. Elkanah Williams the first to deliver a course of lectures on ophthalmology in this country. But such a statement is surely incorrect. Dr. Elkanah Williams was indeed the first in America to deliver a course of *didactic* lectures on ophthalmology, but the first to lecture (clinically it was) on our specialty was Dr. Henry Willard Williams, of Boston, who, in 1850, gave a clinical course in ophthalmology to a class of students at the Harvard Medical School.

Dr. Elkanah Williams died Oct. 5, 1888, the year in which the present writer received his medical degree—a juxtaposition of facts which is made for the purpose of illustrating how brief a period of time has been consumed by the development of ophthalmology in America.

We have said that the first in America to deliver a course of lectures

on the eye was Dr. Henry Willard Williams, of Boston. This distinguished pioneer in ophthalmology was born at Boston, Dec. 11, 1821, son of Willard and Elizabeth Osgood, Williams, and received his general education in the Latin School at Boston and Salem. For a time he studied medicine at Harvard, but, at the end of his second course of lectures, proceeded to Europe, where he studied medicine three years more, and, at length, returning to Harvard, there received his medical degree in 1849.

In 1850 he became instructor in the theory and practice of medicine in the Boylston Medical School, a position which he held for five years. In 1850, furthermore, he delivered to a class of Harvard medical students a course of clinical lectures on diseases of the eye, apart, that is, from any other lectures, as for example on medicine in general or general surgery. In course of time the Doctor relinquished absolutely all his practice excepting only that pertaining to the eye. Thus he may really have been the first in America to practise ophthalmology exclusively, inasmuch as Elkanah Williams, of Cincinnati, would seem to have practised oto-laryngology, as well as ophthalmology, to the end of his career.[83]

Dr. Henry Willard Williams was also one of the founders, in 1864, of The American Ophthalmological Society, the first of its kind in America, and was for many years its president.

Dr. Williams, as the result of a severe attack of influenza, resigned, in the spring of 1891, both his teaching position and his hospital appointments. On so doing, he endowed at Harvard the chair he had just given up. From the effects of the influenza he never fully recovered. He died, without suffering, early in the morning of June 13, 1895, no doubt the most remarkable man in American ophthalmology.

These, then, are the "firsts" in American ophthalmology: The first eye hospital, by Dr. Elisha North, at New London, Conn., in 1817; the first ophthalmic treatise, by Dr. George Frick, of Baltimore, in 1823; the first separate course of clinical lectures on the eye, by Dr. Henry Willard Williams, of Boston, at the Harvard Medical School, in 1850; the first restriction of a practice to the eye, ear, nose and throat, by Dr. Elkanah Williams, of Cincinnati, in 1855; and the first didactic lectures on the eye, by Dr. Elkanah Williams, at the Miami Medical

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[83] Perhaps it may be pardonable to direct attention to the really remarkable rôle which the name of Williams has played in American ophthalmology. The first to attempt a demonstration of a foreign body in the eyeball by means of a radiograph was made by Dr. H. F. Williams (not an ophthalmologist) of Boston, and the first successful attempt to remove such a body so shown, was made by Dr. Charles H. Williams (ophthalmologist) of the same city—both of these physicians being sons of Dr. Henry Willard Williams.

College, in 1860. In addition, Dr. Henry Willard Williams was the first to restrict a practice to the eye alone, and was (with others) a founder of the first society of ophthalmology in America—the American Ophthalmological Society, in 1864.

There were, however, in addition to the men who were first in these various matters, a number of important pioneers, whom now we will briefly consider.[84]

A famous early American obstetrician and pediatrist, who devoted considerable attention to ophthalmology, was Edward Delafield. Born in 1795, he received the degree of Bachelor of Arts at Yale College in 1812 and his medical degree at the College of Physicians and Surgeons in the City of New York in 1815. In company with Dr. John Kearney Rogers he studied for a time in Europe, and, after his return to New York, these two men together organized, in 1820, the New York Eye Infirmary. Here he practised as ophthalmologist, and lectured on diseases of the eye for many years.

He wrote but little, being far too busy with other matters. A few reports by him, however, appear in the early volumes of the American Ophthalmological Society, of which he was one of the founders—a matter of which we shall speak hereafter. He also edited one American edition of "*Travers on the Eye.*"

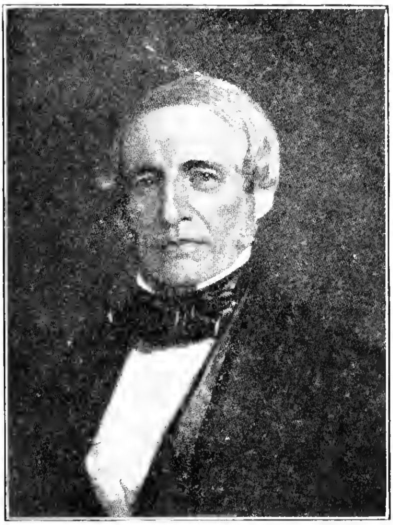
He died Feb. 13, 1875.

A close contemporary of Edward Delafield was Isaac Hays, ophthalmologist, medico-economist, author and editor. Born at Philadelphia, July 5, 1796, he received the degree of A. B. at the University of Pennsylvania in 1816, and that of M. D. at Yale in 1820. He then, for a time, devoted himself especially to the study of ophthalmology.

In 1822 he became surgeon to the Pennsylvania Infirmary for Diseases of the Eye and Ear, and, beginning in 1834, he was surgeon to the Wills Eye Hospital for twenty years. He reported the first case of

[84] There was a very early American ophthalmologist, whom we do not here include—Dr. William Charles Wells. He was born in Charleston, S. C., in 1757, but, in 1764, when only seven years of age, was sent by his parents to Scotland (the country of their origin) for the sake of a better schooling than could be had at that time in America. Returning to Charleston in 1771, he there studied medicine with a Dr. Alexander Garden for about four years, but then returned to Edinburgh University, where he received the degree of Doctor in Medicine in 1780. After four more years in South Carolina, he proceeded to London, where he lived for the rest of his life. In London, he practised chiefly as ophthalmologist, and published, in fact, a book entitled, "*An Essay on Single Vision*" (London, 1792). Wells is not, however, to be regarded as an American ophthalmologist, for, as pointed out by Hirschberg (*Amerikas Augenärzte im 19. Jahrhundert*, p. 27) if Wells is to be regarded as an American, then all such German immigrants to America as Hermann Knapp would have to be regarded as Germans. Hirschberg, however, and most unfortunately, persistently calls Wells "Bell."

astigmatism observed in America, and the fifth in all the world. He was also the first to report a case (that of Mary Bishop) of pathologic (not congenital) color-blindness.[85] In February, 1826, he became one of the editors of the "*Philadelphia Journal of the Medical and Physical Sciences*," which had been established six years before. A few months later, Dr. Hays was made sole editor of this journal, and then it was that he exchanged its title for one much better known, "*The American*



Dr. Isaac Hays (1796-1879).

Journal of the Medical Sciences." In 1869 he began to be assisted in his work as editor by his son, Dr. I. Minis Hays, but continued to act as editor-in-chief until his death—over fifty-two years.

Dr. Hays was never a teacher of medicine—a fact, no doubt, in some part due to his natural timidity before an audience.

Dr. Hays died, April 12, 1879, aged 83.

Of equal eminence was Philip Syng Physick, renowned as an operator on the eye, especially for cataract and artificial pupil, and also the inventor of the first tonsillotome.[86] Born in Philadelphia in 1768, he became, twenty years later, a private student of the great John Hunter, in whose house he roomed. In 1792 he received the degree of M. D. at Edinburgh University. Returning to Philadelphia, he became

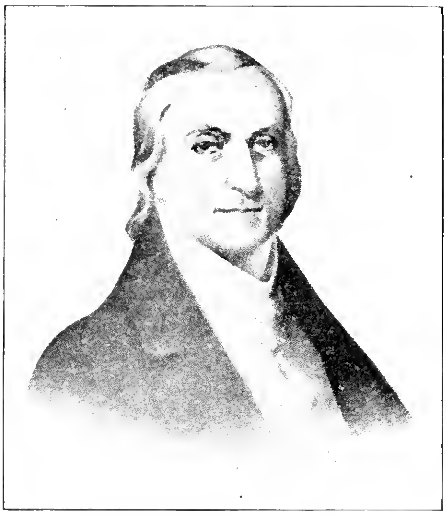
[85] The first case of congenital color-blindness (Daltonism) was that of John Dalton (already mentioned in the fourth division of this article) reported by himself.

[86] This was the "push" tonsillotome. The "pull" instrument was invented by Wm. M. Fahnestock, also of Philadelphia.

at once successful both as a general and as a special operator. He invented a punch forcep, wherewith to remove a piece of the iris for artificial pupil. He died in 1837.

A man of slight importance was John Harper. A native of Ireland, the date of his birth unknown, he received the medical degree at Glasgow, and emigrated to America, settling in Baltimore. He was widely known as a cataract operator, and died in 1831.

A somewhat better ophthalmologist was Horatio Gates Jameson, who was born at York, Pa., in 1788, received the medical degree in 1813 at



Dr. Philip Syng Physick (1768-1837).

the University of Maryland, and settled in Baltimore. He was widely known as an operator on the eye, and wrote a considerable number of ophthalmic articles. He died at Baltimore in 1855.

An early American surgeon who aspired to be an ophthalmologist, was John Mason Gibson, whose life dates are unknown. He published in 1832 a book entitled "*Condensation of Matter upon the Anatomy, Surgical Operations and Treatment of Diseases of the Eye*" (Baltimore, 1832)—an almost valueless affair. It was, however, the second American work on ophthalmology.

A more successful and deserving ophthalmologist of the same surname was William Gibson. Not only was he the first in all history to tie the common iliac artery in the living human subject, but he was also an excellent ophthalmic operator, and, no doubt, the first in history to perform a strabismus operation. Born in Baltimore in 1788, he received

the degree of A. B. at Princeton, and in 1809 the medical degree at Edinburgh. After a very eventful life in Europe, he returned to America, settling in Baltimore in 1811. In 1812 he tied the common iliac artery. He removed, about 1820, to Philadelphia, where he practised till 1855. For a number of years he travelled about the world for pleasure, and died at Savannah, Ga., in 1868, aged 80.

Gibson, as we have said, was the first in history to perform the strabismus operation.[87] He, however, neglected to record his operation in due time; hence the priority is commonly (and quite properly) assigned to Dieffenbach. Dieffenbach's date is 1839, while Gibson's is 1818—a very considerable difference in time. Gibson, however, was led by the very celebrated Dr. Philip Syng Physick—a sort of Jupiter omnipotens of the day—"to abandon these experiments," which leads us to recall once more the pitiful story of Babbage and *his* reliance on *his* authority.

Dr. Gibson also invented the "seton method" for producing the absorption of cataract, as well as a pair of "cataract scissors."

A man of much importance in his day was James Bolton.[88] Born at Savannah, Ga., June 5, 1812, he received the degree of A. B. at Columbia in 1831. In 1836 he received the medical degree at the College of Physicians and Surgeons in the City of New York. Turning his attention to ophthalmology and otology, he became a pupil of Dr. Kearney Rogers. He published in 1843 "*A Treastise on Strabismus, With a Description of New Instruments Designed to Improve the Operation for its Cure, in Simplicity, Ease and Safety.*" The book is clearly written, and presents an excellent summary of the strabismology of the time. Dr. Bolton practised later at Richmond, Va., until the beginning of the Civil War, when he entered the Southern army as surgeon. At the close of the war, he returned to his practice in Richmond, there dying of Bright's disease on May 15, 1869.

Even a more celebrated man than William Gibson was William Edmonds Horner,[89] who discovered in 1822 "Horner's muscle," i. e., the *tensor tarsi*, and who first explained satisfactorily the passage of the tears from the conjunctival sac to the nose. Born at Warrenton, Vauquier County, Va., June 3, 1793, he received the degree of Doctor in Medicine at Philadelphia in 1814. For a time he was a surgeon's mate in the U. S. Army, but in 1816 settled in Philadelphia. There he became prosector, in 1819 adjunct professor, and in 1831 titular pro-

[87] For a complete account of Gibson's operation, see **Gibson, William.**

[88] Whom, however, neither Hubbell nor Hirschberg mentions.

[89] The portrait of Horner is shown in connection with his sketch; and, in fact, the portraits of many other ophthalmologists, mentioned herein, are likewise presented in connection with the sketches of their subjects.

fessor, of anatomy, in the University of Pennsylvania. In 1847 he founded St. Joseph's Hospital. For a time he studied in Europe. Returning to Philadelphia, he practised there until his death, Jan. 23, 1853.

Horner's only writings on the eye are those which deal with the muscle discovered by him. These, which are three in number, are given in full in Vol. VIII of this *Encyclopedia.* See **Horner, William Edmonds.**

Born in the very same year as William Horner, was a famous American surgeon, John Kearney Rodgers, of much importance for the later development of American ophthalmology. Born in New York City in 1793, he received his training in the liberal arts at Princeton College, and afterwards studied medicine with a preceptor, Dr. Wright Post, in New York. In 1816 he received his degree from the college of Physicians and Surgeons. After a term as house surgeon at the New York Hospital, he proceeded to London in company with Dr. Edward Delafield. Soon these two were greatly interested in ophthalmology, and, returning to New York, they, in collaboration with a number of others, established in 1820 the New York Eye Infirmary—to be mentioned again hereafter. For very many years Dr. Rodgers was surgeon to this institution, and some of the more important later ophthalmologists—for example, Dr. Cornelius Rea Agnew—were students (and sometimes protegés) of his. Even William Gibson was, as we have said, a pupil of Rodgers, though of exactly the same age.

Rodger's chief performance was the tying of the left subclavian artery (in 1845) within the scaleni muscles—a procedure which he, so far as I have been able to ascertain, was the first to execute upon the living human subject. As an operator on the eye, he was swift, bold, and brilliant. He wrote but little.

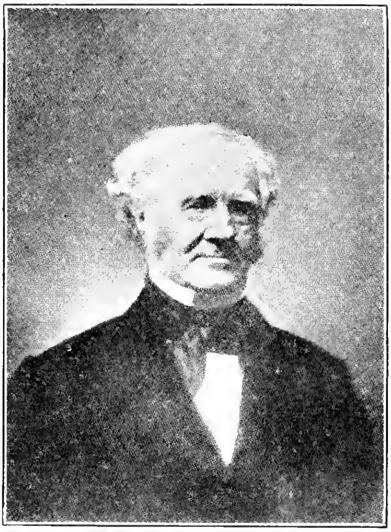
Rodgers died in 1851, of "phlebitis of the liver, followed by peritonitis."

Edward Reynolds, a famous American surgeon, was one of the founders of the Massachusetts Charitable Eye and Ear Infirmary. Born at Boston, Mass., in February, 1793, he received the degree of A. B. at Harvard College in 1811, and, for a time, was engaged in the study of medicine with Dr. John Collins Warren. Then for three full years he studied at Paris and London, in the latter city coming under the influence of Sir William Lawrence, who turned his attention strongly toward diseases of the eye.

Returning to Boston, Dr. Reynolds found his aged father blind from double-sided cataract. With a boldness rare enough among operators even at the present day, he couched both lenses at a single sitting, and

both the couchments were brilliantly successful. The cataract operation had not previously been performed at all in Boston, and the consequence was that Reynolds was a made man.

In 1824 Dr. Reynolds, together with Dr. John Jeffries, "established a dispensary which developed into the well known Massachusetts Charitable Eye and Ear Infirmary." Jeffries, for a time, was senior surgeon, but, upon his resignation, the vacancy was filled by Reynolds.



Dr. Edward Reynolds (1793-1881).

In 1864, at the founding of the American Ophthalmological Society, Reynolds was made an honorary member.

He died at Boston, in 1881, being eighty-nine years of age.

George McClellan was a well known surgeon and ophthalmologist, founder (at the age of twenty-five) of the Institution for Diseases of the Eye and Ear in Philadelphia and one of the founders of the Jefferson Medical College. Born at Woodstock, Conn., in 1796, he received his degree in arts at Yale in 1815, and four years later his medical degree at the University of Pennsylvania. He practised in Philadelphia for very many years, and died in that city in 1847.

Another of the men in this very early group was Nathan Ryno Smith, son of the more distinguished Nathan Smith, and grandfather of Dr. Samuel Theobald, of Baltimore. Born at Concord, N. H., in 1797, he received both his classical and his medical education at Yale University, in which institution his father was a professor. His medical degree

was received in 1823. He taught for a time in medical schools at Philadelphia, and Lexington, Ky., but spent the greater portion of his life as teacher and practitioner at Baltimore. He was widely known as an operator on the eye, and invented a number of useful ophthalmic instruments. The most important of these is his knife for dividing strictures of the nasal ducts. He died in Baltimore in 1887.

Another early ophthalmologist was Squier Littell, author of the once well known "*Manual of Diseases of the Eye.*" Born at Burlington, N. J., in 1803, he received his medical degree at the University of Pennsylvania in 1824. He practised for the most of his life in Philadelphia, and was widely known as an operator on the eye. He died July 4, 1886.

The famous general surgeon, Samuel David Gross, was also widely known as an operator on the eye. Born near Easton, Penn., in 1805, he received his medical degree at the Jefferson Medical College in 1828. His graduation thesis was entitled "The Nature and Treatment of Cataract." He practised at Philadelphia, Easton, Cincinnati, Ohio, Louisville, Ky., New York City, Louisville again, and finally (beginning in 1856) once more in Philadelphia. Here his renown became world-wide. After the reception of numerous honors, he died in May, 1884.

Still speaking of the early group, Alfred Charles Post, a famous general surgeon, was also a very successful ophthalmologist, and author (in 1841) of a tiny book entitled "*Observations on the Cure of Strabismus.*" He was born in New York City in 1806 and died in 1886.

It is proper to include (so close are the ties of language, blood, and physical propinquity) in the group of American ophthalmologists of any given period, the more important Canadian brothers in our art who flourished contemporarily with them. Henry Howard, then, was a famous Canadian ophthalmologist and author of the earliest textbook on the eye to be issued in the Dominion of Canada. Born at Nenagh, County Tipperary, Ireland, Dec. 1, 1815, he received his early education in his native town. He studied his profession at Dublin, receiving the degrees of M. D. and M. R. C. S., the latter in 1838. After practising in Dublin for a number of years, he emigrated, in 1841, to Canada. For a time he engaged in general practice on Amherst Island, U. C., then at Kingston. At length he removed to Montreal, where he practised the eye, ear, nose and throat exclusively. From 1845 until his death he contributed a number of articles on the eye, ear, nose and throat to the *Dublin Medical Journal.* He also wrote at some length and rather frequently for the *British American Journal of Montreal.* About 1860

he wrote a brochure entitled "*The Physiology of Insanity, Crime, and Responsibility.*" In 1861 he was appointed Medical Superintendent of the Lunatic Asylum, of St. John's, L. C., later at Longue Pointe, Montreal, a position which he held until his death, Mar. 28, 1889.

The chief ophthalmic writing of Dr. Howard was his justly famous textbook, entitled, "*The Anatomy, Physiology, and Pathology of the Eye*" (London: John Churchill; Montreal: Armour and Ramsey, 1850). Thus, then, the first Canadian treatise on the eye appeared twenty-seven years later than the first American. The style of the book, however, is better than that of Frick's, and the matter is less dependent on a European model.

Another Canadian ophthalmologist of note was Frank Buller. Born about 1840, at Campbellford, Ohio, he received the degree of Doctor in Medicine at Victoria College in 1869. For the next two years he studied physiology, as well as ophthalmology and oto-laryngology in Germany, chiefly under Helmholtz and von Graefe. From 1872 till 1876 he studied and practised in London, where, in fact, he introduced the direct method of ophthalmoscopy.

Returning to Canada in 1876, he settled as ophthalmologist and oto-laryngologist in Montreal, and received a number of hospital appointments. He was professor of ophthalmology and otology in McGill University for twenty-two years. He will always be remembered as the inventor of the Buller eye-shield (composed of a watch-crystal and strips of sticking-plaster, and oftenest employed to protect an unaffected eye when its fellow is afflicted with gonorrheal infection). He also invented the temporary tying of the canaliculi for the prevention of wound-infection in operations on the eye-ball, and the Buller trial-frame.

Dr. Buller died, Oct. 11, 1905.

Returning now to American ophthalmologists, as contradistinguished from Canadian, we first consider Edward Hartshorne, more famous perhaps as a general physician, but still of some importance in the chain of development of American ophthalmology. Born in 1818, he received his medical degree at the University of Pennsylvania in 1840. Having studied in Europe for a number of years, he settled in Philadelphia and soon was widely known. In his practice he paid considerable attention to diseases of the eye, and in 1856 he edited the second American issue of T. Wharton Jones's "*Principles and Practice of Ophthalmic Surgery*" (Phila., Lee and Blanchard, 1856). Hartshorne died in 1885.

The last of the "early" group of American ophthalmologists, as perhaps they may be called, was Joseph Leconte, physiologist and

all round naturalist as well as family doctor and specialist on the eye. He was born in 1823, received the degree of doctor in medicine at the College of Physicians and Surgeons in New York City, and practised general medicine at Macon, Ga., for a number of years. In 1850-51 he studied geology with Agassiz at Harvard. He also taught at Oglethorp College, and the University of South Carolina, was a chemist in the Confederate Laboratory for two or three years, and in 1869 was called to the University of California, where he taught the natural sciences for thirty-two years.

Leconte's most remarkable performance in ophthalmology was the volume called "*Sight*"—a work so well described in Dr. Eaton's sketch of Leconte in this *Encyclopedia*, that here we may merely add that the subject of binocular vision received in this volume the fullest and most adequate treatment which had ever been accorded to it at that time—1881.

Leconte died in 1901, aged 78.

B. The Later Group.

Coming to a somewhat later period, we first consider the Chicago men, inasmuch as the first of these began to be active as ophthalmologists somewhat earlier than the first of the later group in New York. The Chicago group in question consists of Holmes, Hildreth, Jones, Jacobson, Hotz, Smith, Bettman, Gradle, and Coleman. Dr. Edward Lorenzo Holmes, of Chicago, the earliest of the group, was born some ten years later (i. e. in 1828) than Dr. Edward Hartshorne, and five years later than Leconte. In 1854 he received his medical degree at Harvard, and spent the following year as interne in the Massachusetts General Hospital, making a specialty of ophthalmology and otology. For further study in these subjects he proceeded to Europe, where he remained for a year and a half.

Returning to America, he settled in Chicago, where he was almost immediately successful. There was hardly a medical, especially ophthalmologic movement in the State of Illinois in which, up to the time of Dr. Holmes's death, he had not a guiding hand. In 1858 he founded the Illinois Eye and Ear Infirmary at Adams and Peoria Streets, of which we shall speak again under "Eye Hospitals and Infirmaries." He was an honorary member of the ophthalmological and otological societies.

In 1860 he was appointed lecturer on ophthalmology and otology in the Rush Medical College. In 1867 he received the full professorship, a position which he filled with distinguished ability until his resignation

in 1898, thirty-one years. He was President of the school from 1890 to '98.

For a time he was editor of the *Chicago Medical Journal.* His contributions to ophthalmology and otology, both in that publication and in others, are numerous and valuable.

Dr. Holmes died Feb. 12, 1900.

Next after Holmes came Joseph Sullivan Hildreth, who founded the Desmarres Hospital, which, though it afterwards became the Cook County Hospital, was limited at first to the treatment of diseases of the eye and ear. Hildreth was born at Cohassett, Norfolk County, Mass., May 1, 1832, being related in some degree to Richard Hildreth, the historian. Having received his medical degree at the University of Pennsylvania in 1856, he studied for a number of years under Demarres at Paris, becoming, in fact, the Superintendent of Desmarres's Eye and Ear Institute.

Returning to America, he settled at Detroit, Mich., but soon was appointed by the Government to establish at Chicago a hospital for the treatment of eye and ear diseases. This he did in 1863, calling the institution "The Desmarres Hospital." The building stood at the corner of 18th and Arnold Streets, and accommodated about 130 patients. It lasted, however, as an eye and ear hospital for only three years, becoming in 1866 the Cook County Hospital.

Dr. Hildreth was the first professor of ophthalmology at the Chicago Medical College, and ophthalmic surgeon to a number of general hospitals. His articles on ophthalmology were very numerous.

He died of gelsemium poisoning July 22d, 1870.

Next after Hildreth came Samuel Jones Jones, who was born in Pennsylvania in 1836. His medical degree was received at the Pennsylvania University in 1860. Having served in the U. S. Navy throughout the Civil War, he studied ophthalmology and otology abroad for a year, and, returning to America, settled in Chicago. He was active in the development of ophthalmic societies and hospitals, though a founder of none. He died in 1901, aged 65.

Another important Chicago ophthalmologist was Daniel Sigismund Jacobson, who was born of Jewish parents at Copenhagen, Denmark, Feb. 14, 1837, and who, at first, was a student of Hebrew theology. Having received the Ph.D. in 1856 and the M. D. in 1862, both at the Copenhagen University, he served for a time as military surgeon in the Schleswig-Holstein War, but settled in Chicago in 1866, devoting especial attention to gynecology and ophthalmology. In 1872 he founded at 303 Wabash Avenue a private ophthalmic hospital, which,

however, was destroyed in the following year by the great fire. He was, for a time, an ophthalmologist exclusively, but soon returned to general practice. He was, nevertheless, an influential man in early Chicago ophthalmology. He died at Copenhagen, Feb. 23, 1894.

Next came Hotz, a man of great inventive ability, who devised a number of operations which are still in use. Most widely known of these, perhaps, are his various operations for trichiasis, ectropion, and entropion, which are fully described in the non-historic portions of this *Encyclopedia*. Born at Wertheim, Germany, in 1843, he received his medical degree at Heidelberg in 1865. He settled in Chicago in 1869, was widely celebrated as operator and teacher, and died in 1908.

A less important man than Hotz, but still an ophthalmologist of considerable prominence, was William F. Smith. After a number of years in ophthalmic study at Heidelberg, he settled in San Francisco about 1869, but in 1884 removed to Chicago. He had an enormous practice, and was a good operator. He was ophthalmologist to a number of hospitals. At the Cook County Hospital he succeeded D. S. Jacobson as ophthalmic surgeon, and was in turn succeeded by Boerne Bettmann. He died at Chicago in April, 1901.

Boerne Bettman, like Smith, was known especially as an operator, but yet he was more important in the development of ophthalmology in America, inasmuch as a number of eminent American ophthalmologists and teachers of ophthalmology were, at one time or another, among his pupils. Bettman was the first lecturer on ophthalmology and otology in the Chicago College of Physicians and Surgeons. He was born at Cincinnati in 1856, and died at Chicago in 1906, aged only 50.

"The Little Giant," Henry Gradle, was noted especially as an operator, but was also active in early society and hospital development. As a teacher of ophthalmic surgery he was unexcelled.

Born at Frankfort-on-the-Main, Germany, in 1855, he received his medical degree in 1874 at the Chicago Medical College. Later he studied ophthalmology and oto-laryngology at Vienna, Heidelberg, and other European universities. He died in 1911.

W. Franklin Coleman was the last of this early group of ophthalmologists in Chicago, so far as these have now departed. Born at Brockville, Ont., Canada, in 1838, he received his medical degree at Queen's Medical School, Kingston, Canada, in 1863, and his M. R. C. S. (England) in 1870. For a time he practised as ophthalmologist and oto-laryngologist in Toronto, but, after a year of further study at Vienna and Heidelberg, settled in St. John, N. B., where, according to Dr. C. H. Long, he was for seven years "the only oculist in the twin provinces of New Brunswick and Nova Scotia."

In 1885 he removed to Chicago, where he was one of the founders of both the Polyclinic and Post-Graduate Medical Schools. In the latter institution he was, for many years, president and professor of ophthalmology. He wrote a great deal on ophthalmology, and was one of the contributors to this *Encyclopedia*. Especially valuable were his articles in this and other works, on the subject of electricity in ophthalmology.

Dr. Coleman died at Federal Point, Florida, Jan. 22, 1917, aged 79.

Next comes the group of later New Yorkers. A prince among these, and in the profession generally, was Cornelius Rea Agnew, who was born in New York City Aug. 8, 1830, and died there April 18, 1888, being, therefore, at his death, but fifty-eight years of age. As already said, he was one of the pupils of Dr. J. Kearney Rodgers. In 1852 he received the medical degree at the College of Physicians and Surgeons in the City of New York.

For a time Dr. Agnew practised in a village which is now Houghton, Mich. Receiving, however, in 1855, the appointment of surgeon to the Eye and Ear Infirmary of New York City, he returned to that place. Soon after, he sailed for Europe to prepare himself still further for the arduous duties of his new position. In Europe he studied chiefly under William Wilde, William Bowman, George Critchett, Sichel, and Desmarres.

Returning to New York in 1855, Dr. Agnew entered on a career as general practitioner, and soon was appointed Surgeon General of the state. Three years later, he was a medical director of the New York Volunteer Hospital. In his later years, he devoted himself exclusively to diseases of the eye, ear, nose and throat.

Dr. Agnew was a man of strongly marked and wholly natural executive ability. Hence it was that, first and foremost, he was a founder of institutions. He was one of four to start the Union League Club of New York City. He assisted, in 1864, in organizing the School of Mines of Columbia. In 1866, at the request of the entire faculty, he established an ophthalmic clinic in the College of Physicians and Surgeons of New York. Two years later he brought into existence the Brooklyn Eye and Ear Hospital, and, the following year, the Manhattan Eye and Ear Hospital of New York. He was also one of the founders of the New York Ophthalmological Society.

In 1869 he was elected to the clinical professorship of Diseases of the Eye and Ear in the College of Physicians and Surgeons—a position which he held till his death.

Dr. Agnew's contributions to ophthalmic literature and his inventions were numerous and valuable. He devised, for example, an excellent operation for divergent strabismus, which he described in detail in

the *Transactions of the American Ophthalmological Society*, for 1886, p. 31, under the title, "A Method of Operating for Divergent Squint." His "operation for thickened capsule" is also an important procedure, often described today by European ophthalmologists even in their smaller manuals, while Agnew's "cantholysis," a modification of von Ammon's canthoplasty, is in use by almost every ophthalmologist. Agnew's bident, or double needle, for the extraction of lenses from the vitreous humor, his enucleation operation, chalazion operation, peritomy for pannus, and secondary cataract operation, are also very well known, and are fully described in Vol. I of this *Encyclopedia*, pp. 195-197 inclusive.

One of the most remarkable figures in American ophthalmology, and second in time of the great New York trio, was Herman Jakob Knapp. Born two years later than Agnew, i. e., in 1832, at Dauborn, Germany, he at first designed to be a poet, but later decided for medicine. His medical degree was received at Giessen in 1854. He then studied ophthalmology at Paris, London, Utrecht and Heidelberg. For a time he was assistant to Albrecht von Graefe, the inventor of iridectomy for glaucoma. He was privatdocent for, later full professor in, ophthalmology at Heidelberg, and founder of the first University Eye Clinic at that place.

In 1868 he removed to New York City, where he founded at once a private clinic for diseases of the eye and ear—the New York Ophthalmic and Aural Institute—now the Knapp Memorial Eye Hospital—the greatest institution of its kind this side of the Atlantic. Of this immense affair, however, more hereafter.

In 1869, Knapp founded, together with Moos, the "*Archiv f. Augen- und Ohrenheilkunde*," which, ten years later, was divided into the "*Archiv f. Augenheilkunde*," (edited by Knapp and J. Hirschberg, Berlin) and the "*Archiv f. Ohrenheilkunde*," (edited by Knapp and Moos). An English edition of each of these three periodicals was published from the very beginning, and, after the division of the parent journal, Knapp continued in charge of the English edition of both the resultant publications. The original papers in the English edition "appeared in the German (*Archiv für Augenheilkunde*) either in full or in more or less abridged translations, and *vice versa*."

In 1882 Knapp became professor of ophthalmology at the medical department of the University of the City of New York—a position which he held till 1888—when he accepted the like chair at the College of Physicians and Surgeons, being the Medical Department of Columbia University. In 1903 he was made emeritus professor at this institution.

Knapp was a great inventor of ophthalmic instruments. His improved lid forceps, roller forceps for trachoma, needle knife, ophthalmotrope, ophthalmoscope, cystotome, operating chair, etc., are thoroughly described, and, for the most part, pictured in the non-historical portions of this *Encyclopedia*. For a list of his writings, as well as a description of the man himself, see, herein, **Knapp, Hermann Jakob.**

The third of the New York trio was Henry Dewey Noyes, author of the celebrated text-book, "*Diseases of the Eye*," one of the founders of the American Ophthalmological Society, and an operator on the eye of international reputation. Born in the very same year as Hermann Knapp, but in New York City, he received his liberal training at the New York University, and his medical degree at the College of Physicians and Surgeons in the City of New York. After about four years of graduate study, the last one spent in Europe, he settled as ophthalmologist and oto-laryngologist in 1859 at New York City.

For many years he was on the staff of the New York Eye and Ear Infirmary, and taught at Bellevue Hospital Medical College from 1868 till 1900.

His book, "*Diseases of the Eye*," appeared in 1890, a second edition in 1894.

Dr. Noyes died of pneumonia at his summer home, in Mt. Washington, Mass., in 1900, aged 68. He was one of the greatest forces in the development of American ophthalmology.

It is here convenient to consider what may well be termed "the St. Louis Group"—i. e., Pollak, Michel, Green, Parker and Post. Simon Pollak was the earliest ophthalmologist in St. Louis, and also founder of the first eye and ear clinic in that city. Born at Prague, Bohemia, in 1814, he received the medical degree in 1835 at the University of Vienna. Two years later he came to America, and from 1838 to 1844 practised at Nashville, Tennessee. Removing to St. Louis, he practised there for fifty-eight years. He was one of the founders, in 1852, of the Missouri School for the Blind, and in 1860 of the eye and ear clinic at Mullanphy Hospital, the first of its kind, as stated above, in St. Louis.

Dr. Pollak died Oct. 31, 1903, aged almost 90.

Next oldest of the St. Louis quintet was Charles Eugene Michel, who was first to treat trichiasis by means of the electrolytic needle. He was born at Charleston, S. C., in 1832, received his degree at the Medical College of the State of South Carolina, and served as a surgeon in the Confederate Army through the whole of the Civil War. From 1865 until his death he practised ophthalmology at St. Louis. For

many years he was professer of ophthalmology at the Missouri Medical College. He died at St. Louis, Sept. 29, 1913.

One can hardly think of Charles Eugene Michel without thinking also of John Green—so long a time were the two simultaneously identified with ophthalmology in St. Louis. Green was born at Worcester, Mass., April 2, 1835, and, after a liberal education, received the degree of M. D. at Harvard in 1866. Prior to this, he had been a student of medicine for two or three years in Europe. Settling in 1866, as ophthalmologist, at St. Louis, he very soon acquired an international reputation. Dr. Green was especially known as an inventor of ophthalmic operations, apparatuses and instruments. Thus, for examples, Green's operation for entropion, Green's extirpation of the lachrymal sac, Green's styles, Green's test-types, etc., are known to every ophthalmologist.[90]

Dr. Green was one of the charter members of the American Otological Society. He was also professor of ophthalmology and otology in the St. Louis College of Physicians and Surgeons, as well as lecturer on ophthalmology at the St. Louis Medical College, for very many years. He died Dec. 7, 1913.

James Pleasant Parker, founder of "*The Annals of Ophthalmology and Otology*," was the fourth of the quintet. Born in Alabama in 1854, he studied and practised pharmacy for several years. His medical degree was received from Jefferson Medical College in 1886. For a year he studied ophthalmology and oto-laryngology in Philadelphia and New York. In 1887 he began to practise at Kansas City, (where, in 1891, he founded "*The Annals of Ophthalmology and Otology*") but removed to St. Louis in 1892. In 1896 he died. The pathetic story of his great self-sacrifice for the journal which he had founded, is told in his sketch in this *Encyclopedia*.

The last of the five St. Louis men was Martin Hayward Post, not so much of an inventor as a man of great operative and executive ability. Born at St. Louis in 1851, he received the medical degree at the St. Louis Medical College in 1877. Having become a student of Dr. John Green, he was later associated with that eminent operator in practice till the latter's decease. Dr. Post was especially able and active in all society work, and, in this way, was one of the factors in the development of ophthalmology in America. The Washington University Eye

[90] It was *not*, however, Dr. John Green (contrary to what I said at the beginning of his *sketch*) who invented Green's tendon-tucker, but Dr. Duff Warren Greene, of Dayton, Ohio—a correction which I gladly make, at the suggestion of Dr. A. E. Ewing.

Hospital is also owing, indirectly, to his influence. He died Sept. 1, 1914.

Returning to the east. Hasket Derby, one of the founders of the American Ophthalmological Society, was born in Boston, in 1835, and after a liberal training in the arts and sciences, studied at the Medical School of Harvard University, where he received the degree in 1851. He seems to have begun to practise ophthalmology in his native city about 1861. By his numerous ophthalmic writings, and even more perhaps by his ability and untiring efforts as an organizer, he contributed very largely to the development of ophthalmology in the United States. He died in 1914.

A very inventive ophthalmologist of Philadelphia was George Cuvier Harlan. Born at Philadelphia in 1835, he received, after the customary training in the liberal arts and sciences, his medical degree at the University of Pennsylvania. He will especially be remembered as the inventor of Harlan's test for malingering and Harlan's symblepharon operation. He also wrote the important articles, "Diseases of the Eyelids" and "Operations Performed Upon the Eyelids" for Vol. III of Norris and Oliver's "*System of Diseases of the Eye.*" He died in 1909.

Herman Althof was one of the founders of the New York Ophthalmological Society and of the American Ophthalmological Society. Born in Germany in 1835, he began to practise as ophthalmologist in New York City in 1858, and died in 1877.

Aaron Friedenwald, first president of the Maryland Ophthalmological Society, and, for a very long time, the only ophthalmologist in Baltimore, was especially known as a writer on ophthalmic subjects. Born at Baltimore in 1835, he received his professional degree in 1860, studied in Europe, settled in Baltimore, there became in 1873 professor of ophthalmology at the College of Physicians and Surgeons, and died in 1902.

Ezra Dyer was the inventor of Dyerizing, still in use. Born at Boston in 1836, he received his medical degree in 1859, studied in Europe, and settled as ophthalmologist in Philadelphia in 1861. He was always active in medical society work, and was one of the founders of the American Ophthalmological Society. He died in 1887.

One of the great developers of ophthalmology in the South was Abner W. Calhoun, of Atlanta. Born at Newman, Ga., he received his medical degree at the Jefferson Medical College in 1869. After a year or more abroad, he settled as ophthalmologist and oto-laryngologist in Atlanta, and was one of the greatest ophthalmologic forces in the South. He was especially active in ophthalmic society work. He died in 1910.

Edward Greely Loring, inventor of the Loring ophthalmoscope (see, herein, **Ophthalmoscope**), and author of the well known "*Textbook on Ophthalmoscopy*," was born in Boston in 1837. He received his medical degree at Harvard and settled in Boston. In 1865 he settled in Baltimore, but, in 1866, removed to New York, where he formed a partnership with Cornelius Rea Agnew. He died in 1888.

Daniel Bennett St. John Roosa, chief of the founders of the New York Post-Graduate Medical School, and one of the founders of the Manhattan Eye and Ear Hospital and of the Brooklyn Eye and Ear Hospital, was born at Bethel, N. Y., in 1838, received his medical degree from the New York University in 1860, studied in Europe, and, in 1863, settled as ophthalmologist and oto-laryngologist exclusively in New York City. As an ophthalmic educator he had few equals. He died in 1908.

William Fisher Norris, whose chief contribution to the development of American ophthalmology consisted of his literary work, was born in Philadelphia in 1839, received his medical degree from the University of Pennsylvania in 1861, served for a time in the War, studied ophthalmology in Europe, and settled as ophthalmologist in 1870 at Philadelphia. He was long a teacher of ophthalmology at the University of Pennsylvania, and was one of the founders of the first eye clinic at that school. He was one of the authors of Norris and Oliver's "*Textbook of Ophthalmology*," and one of the editors of Norris and Oliver's "*System of Diseases of the Eye*." He died in 1901.

The first in any land to call attention to the dangers of blindness from wood-alcohol poisoning was Emil Gruening, of New York. Born at Hohensalza, East Prussia, in 1842, he came to America in 1862. In the very same year he began to study medicine at the College of Physicians and Surgeons in the City of New York, where he received his degree (having been considerably interrupted by services in the war) in 1867.

The next three years he spent in Europe, especially with Albrecht von Graefe. In 1870 he settled as ophthalmologist in New York City. He was long professor of ophthalmology at the New York Polyclinic. He was also very inventive, Gruening's magnet being familiar to every ophthalmologist. He also assisted in the evolution of American ophthalmology by numerous contributions to ophthalmic journals. He died in 1914.

One of the greatest formative influences in American ophthalmology was Leartus Connor. Born at Coldenham, N. Y., in 1843, he received the medical degree at the College of Physicians and Surgeons in New York City in 1870. He settled in Detroit in 1871, and in 1878 began

to restrict his practice to diseases of the eye. He contributed much to ophthalmic literature, and was specially energetic in all society work. He was one of the committee that founded the *Journal of the American Medical Association*, and was also the founder of the "Council of Chemistry and Pharmacy" of the same association—both these services having proved of value to American ophthalmology. He died in 1911.

Alvin Allace Hubbell, of Buffalo, New York, is specially distinguished as the first to write a history of American ophthalmology—"*The Development of Ophthalmology in America*" (Chicago, 1908)—a work to which all later writers must acknowledge themselves indebted. Born at Conewango, N. Y., in 1846, he received the degree of M. D. at the Buffalo University in 1876. Settling at once in Buffalo, he practised medicine in general till 1883, when he decided to limit his practice to ophthalmology. He was an excellent teacher, and extremely serviceable in many ophthalmic societies. He died in 1911. So ends the list of the more important dead in American ophthalmology.

Numerous names have had to be omitted which the writer would gladly have introduced, saving and excepting for the fact that only the *development* of ophthalmology is the subject of consideration here—not American pan-ophthalmo-biography. Of the living he should also like to speak, but this, for manifest reasons, is not permissible.

Passing, therefore, now, from individuals to institutions, we first consider—

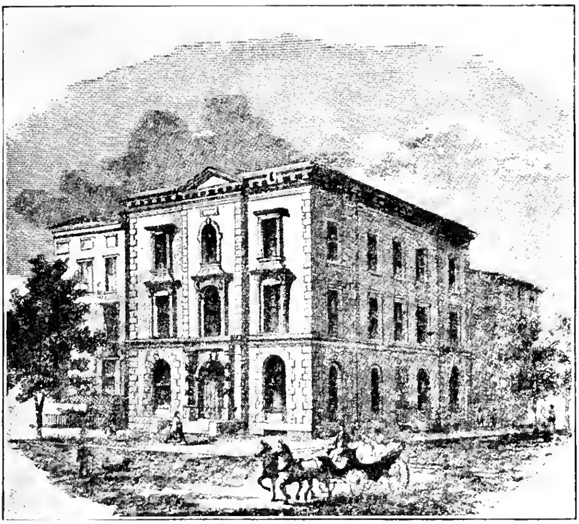
American Eye Hospitals and Infirmaries.

The earliest American institution for the treatment of diseases of the eye, was, as we have seen, "The New London Eye Infirmary," at New London, Conn. This was founded, contrary to the rule in such cases, by an individual,[91] Elisha North. How long this institution lived, is not now ascertainable, but possibly twelve or fourteen years.

The next earliest infirmary for diseases of the eye was founded not by one man, but by two—Edward Delafield and John Kearney Rodgers. This was the New York Eye and Ear Infirmary, which was situated at 45 Chatham St., New York City. It was founded in 1820, and its first officers and directors were as follows: William Few, president; Henry I. Wyckoff, first vice-president; John Hone, second vice-president; John Delafield, Jr., treasurer; James I. Jones, secretary;

[91] "These would now probably be moping about in total darkness and would be a burden to society and themselves had it not been for my *individual* exertions."—North, in "*The Connecticut Gazette.*" The italics are mine.

Nathaniel Richards, Benjamin L. Swan, William Howard, Henry Brevoort, Jr., Joshua Jones, William Howell, James Boggs, Isaac Pierson, Jeromus Johnson, Isaac Collins, Cornelius Heyer, Henry Rankin, Benjamin Strong, Samuel F. Lambert, Edward W. Laight, Gideon Lee. The surgeons were Drs. Edward Delafield and John Kearney Rodgers; the consulting surgeons, Drs. Philip Wright Post and Samuel Borrowe.



New York Eye and Ear Infirmary. First Building. Erected, 1856.

This infirmary was immediately successful and is still in successful operation at Second Avenue and 13th Street. It now supports 175 beds.

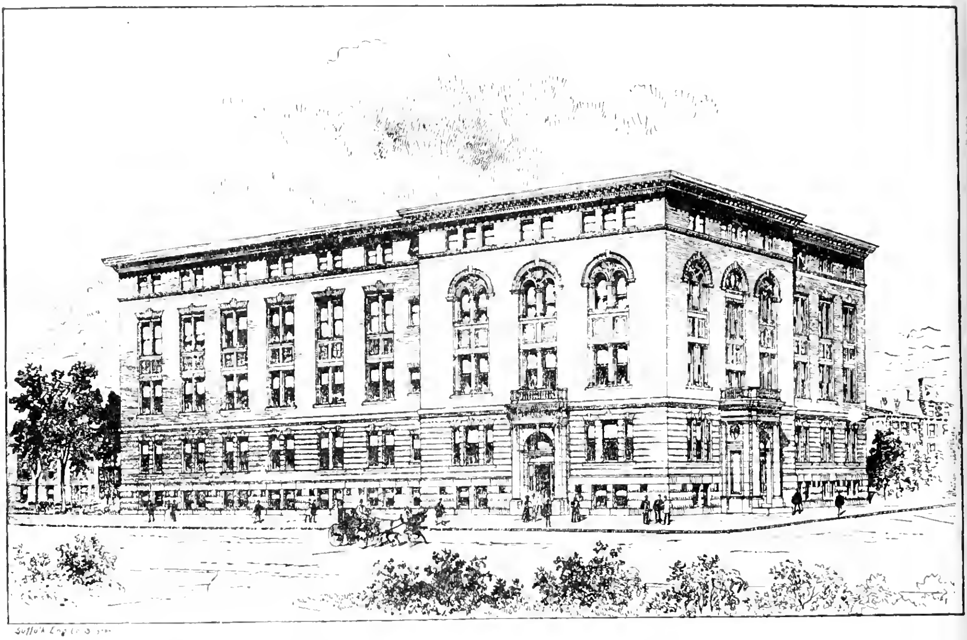
The third ophthalmic hospital in the United States was the Philadelphia Dispensary for Diseases of the Eye, which was founded in 1821 and lived for about four years. The prime mover in this affair was Dr. George McClellan, who later founded the Jefferson Medical College.

The fourth institution of a similar character was also founded in Philadelphia, "The Pennsylvania Infirmary for Diseases of the Eye and Ear." This was started on Feb. 8, 1822, by the following: James Gibson, William Meredith, Charles N. Baucher, Manuel Eyre, Robert M. Patterson, M. D., Clement C. Biddle, William McIlvaine and Richard C. Wood.

This institution was incorporated in 1826, and in 1829 or 1830 was merged, at least in a manner of speaking, in the Wills Eye Hospital,

funds for which much larger institution were provided in the will of James Wills, who died in the year last mentioned. But of this hereafter.

The Massachusetts Charitable Eye and Ear Infirmary was the fifth of its kind in the United States. It was founded in 1824 by Dr. Edward Reynolds and Dr. John Jeffries, and consisted at first of only a single room in the Scollay Building, rented and paid for by the

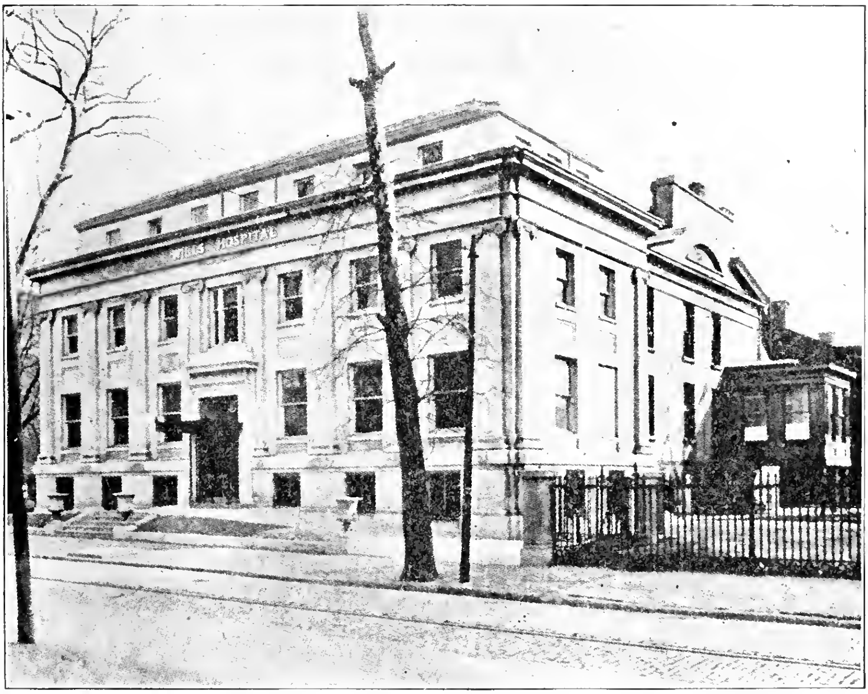


Massachusetts Charitable Eye and Ear Infirmary. Main Building. Completed in March, 1899.

public-spirited founders themselves. It was not till 1827 that the institution was incorporated. It was later moved to a site on Sumner Street, then on Green and finally on Charles Streets.[92] In 1896 the sum of $100,000 was voted to this hospital by the Massachusetts legislature, to which amount were added a number of private subscriptions,

[92] The following is a passage from an address delivered by Reynolds at the dedication of the new building at 233 Charles Street, July 3, 1850: "... In the month of November, 1824, the speaker, in conjunction with Dr. John Jeffries, hired a room in Scollay's buildings; fitted it with such conveniences as their limited means enabled them to procure; and invited the poor, afflicted with diseases of the eye, to come there for gratuitous aid. After having continued their daily attendance for the period of sixteen months, it was found that during this time, although the population of the city did not exceed 50,000, no less than 886 persons had applied at the rooms. ..."

so that, in 1898, an excellent new four-story brick building was erected on the corner of Charles and Fruit Streets. About the present hospital I quote the following from a letter by Dr. Frederick A. Washburn: "It has a capacity of 219 beds. Last year [1916] there were 4,016 cases admitted to the wards, and 76,017 visits were made to the out-patient department. There are fifty-six doctors on the staff, a number of whom are instructors in the Harvard Medical School. Eight



Wills Eye Hospital. New Building. Completed, 1908.

house officers are in constant service at the Hospital. Students in the advanced classes of the Medical School receive instruction in the wards and in the out-patient department."

The sixth ophthalmic hospital was the Baltimore Dispensary for the Cure of Diseases of the Eye. It was started by Frick in 1823, and became defunct some three or four years later.

The Wills Eye Hospital, of Philadelphia, already adverted to, was established in 1832 by a bequest of Mr. James Wills, Jr. The cornerstone was laid in 1832, and on Mar. 3, 1834, the building was opened to the public. The first surgeons were George Fox, Isaac Hays, Squier

Littell, and Isaac Parish. The earliest name of this infirmary was "The Wills Hospital for the Blind and Lame," and the site was on Race Street, between 18th and 19th streets. An out-door department was not created till 1839.

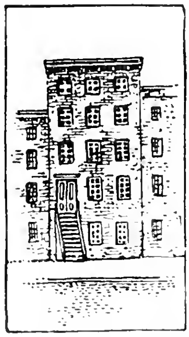
The present medical executive officer is S. Lewis Ziegler. The number of beds is 105. Only diseases of the eye are treated.

The New York Ophthalmic Hospital. New York City.

The earliest ophthalmic hospital in New York was the New York Eye Infirmary, already mentioned. The second in that city was the New York Ophthalmic Hospital, founded in 1852. In 1867 it became, and has ever since remained, exclusively homeopathic. In 1872 systematic instruction on the eye began to be given at this hospital, and, in 1879, "the Legislature of the State of New York, by special enact-

ment, gave to the hospital the power to confer the degree of Oculi et Auris Chirurgus." College and hospital are both still in successful operation at 210 East 23d Street.

The Manhattan Eye and Ear Hospital and the New York Ophthal-



Manhattan Eye and Ear Hospital. First Building, 34th Street.

mic and Aural Institute were organized in the same year, 1869, the former by Cornelius Rea Agnew, the latter by Hermann Knapp.

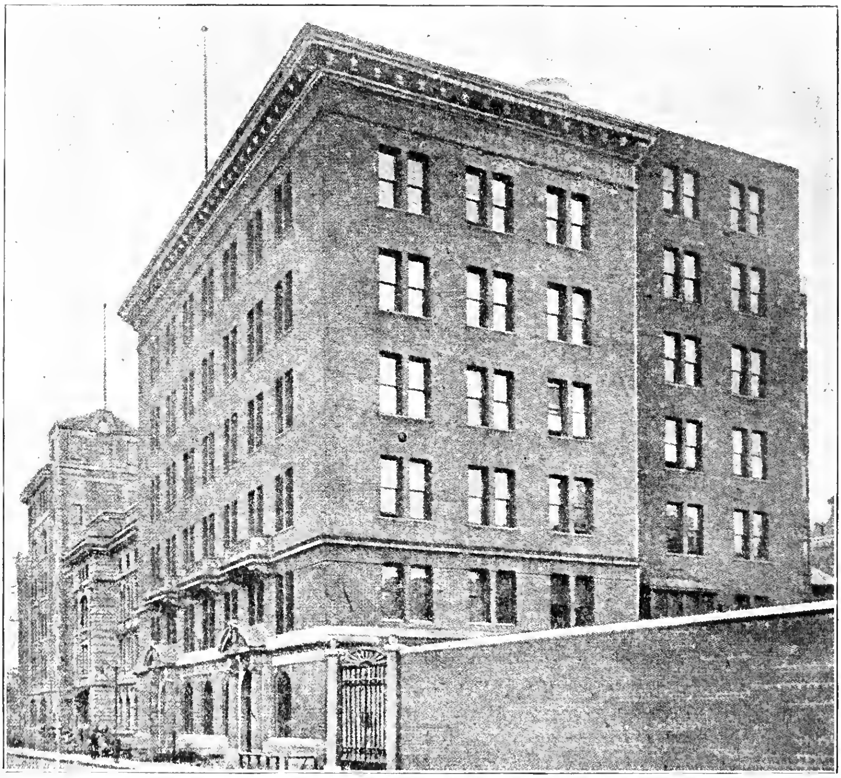
The former was at first in a dwelling on 34th Street, but, in 1881, was removed to a building at the corner of 41st Street and Park Avenue, a structure which cost \$126,498. In 1897 this building was

Manhattan Eye and Ear Hospital. Second Building, 103 Park Avenue.

enlarged at a cost of \$41,000. In a very short time, however, even the very much enlarged quarters were found to be inadequate, and a new site was purchased on 64th Street, near Third Avenue, running through to 63d Street. A six-story building was constructed in 1901 on the 64th Street side, and in 1917 a building on the 63d Street side, for nurses and employes, so that now the value of buildings and equipment alone—exclusive of that of the land—is more than a million dollars.

Fifty nurses are employed, and the attending staff numbers 118. In connection with this hospital is a post-graduate school for nurses and another for physicians who are studying the eye, ear, nose and throat. In the year ending Sept. 30, 1916, there were treated 51,920 new patients.[93]

The New York Ophthalmic and Aural Institute was at first located at 46 East 12th Street. During the first year, only 1,828 patients



Manhattan Eye, Ear and Throat Hospital. Present Building, on 64th Street, near Third Avenue.

were received and treated. In recent years, however, the number has amounted sometimes to as many as 17,000, while at the close of September, 1913, the aggregate number of charity patients only was over 420,000.

In course of time No. 44 East Twelfth Street was purchased by

[93] For the most of my information about this hospital, I am deeply indebted to a letter from Dr. J. Edward Giles.

Dr. Knapp and added to No. 46. After the death of Dr. Knapp the Institute was moved to the south-west corner of 57th Street and Tenth Avenue, its name being changed at the time to "The Knapp Memorial Eye Hospital"—the name it still bears.

Dr. Arnold Knapp, son of Hermann Knapp, is now the physician in charge. There are 45 beds. A full description of this hospital, to-

The Illinois Charitable Eye and Ear Infirmary, at Chicago.

gether with a picture thereof, is given in connection with the sketch of Hermann Knapp, in Vol. IX of this *Encyclopedia.*

Of later institutions we may mention: The Harlem Eye, Ear and Throat Infirmary, at 2099 Lexington Avenue and 127th Street, established in 1881, now with 10 beds. The Bronx Eye and Ear Infirmary, at 459 East 141st Street, established in 1902, now with 12 beds. The Hospital for Contagious Eye Diseases, at 341 Pleasant Avenue, established in 1904, now with 19 beds.

The Chicago Charitable Eye and Ear Infirmary was founded, as

heretofore stated, by Dr. Edward L. Holmes and his associates at the northeast corner of Michigan Avenue and Clark Street in 1858. Four years later it was moved to 28 North Clark Street, while early in 1871 it became an institution of the State, the name being changed to "The Illinois Charitable Eye and Ear Infirmary." The building then in use was destroyed by the great Chicago fire, Oct. 9, 1871. In 1872 the institution was reopened in a rented building on North Morgan Street, while in 1874 the present building, at 904 West Adams Street was erected and occupied.

We have no time to consider here the history of the other ophthalmic hospitals of the United States. Suffice it that, in the present year of 1917, there are, according to "*The Red Book of Eye, Ear, Nose and Throat Specialists*" for 1917, pp. 16-17, no fewer than 58 hospitals and infirmaries that specialize in the treatment of the eye, or of the eye, ear, nose and throat.

Ophthalmological Associations.

The first was the American Ophthalmological Society. This was founded in January, 1864, by Drs. Hasket Derby, of Boston, and F. J. Bumstead and H. D. Noyes of New York. The first meeting was held on the afternoon of June 7, 1864, at the New York Eye and Ear Infirmary. The first paper was read by Dr. Dix on "A Transparent Neoplastic Formation in the Anterior Chamber of the Eye." The society had, at first, some nineteen members; in 1915, however, 196 active members and 3 honorary.

The Section on Ophthalmology of the American Medical Assoeiation was not instituted till 1877, 30 years after the founding of the Association itself. The first chairman was Hermann Knapp, of New York, and the first secretary, X. C. Scott, of Cleveland. The first meeting was held at Atlanta, Ga., on May 6, 1879. Dr. Elkanah Williams, of Cincinnati, read the first paper, the title being "Ivory Exostosis of the Orbit." At first the officers were appointed by a committee selected by the Association in general, one committee member from each state. In 1888, the right to choose its own officers was granted to the Section. The papers at first were published only in the annual volumes of the *A. M. A. Transactions*, from 1883-1891 in the "*Journal*" (which was founded in 1883) and from 1891 till now they have also been reprinted in separate annual volumes of transactions.

The second oldest local ophthalmological society in the world is the New York Ophthalmological Society, founded in March, 1864, therefore in the same year as the American Ophthalmological Society, and

one year later than the Heidelberg Ophthalmological Society. The charter members were: C. R. Agnew, H. Althoff, F. J. Bumstead, W. H. Carmalt, J. H. Hinton, H. D. Noyes, D. B. St. John Roosa, H. B. Sands, F. Simrock and William Stimson. It is still in existence and very active.[94]

The Chicago Ophthalmological and Otological Society was founded by Dr. Boerne Bettman about 1883. Dr. Bettman was secretary until the dissolution of the organization in 1889. In 1893 the Society was revived by Dr. C. P. Pinckard. The first meeting was held in Weber's restaurant. The first president was Dr. E. L. Holmes, and the first secretary, Dr. C. P. Pinckard, who served for nine years. The charter members, as recalled by Dr. Casey A. Wood, were: George F. Fiske, Samuel J. Jones, C. P. Pinckard, F. C. Hotz, Henry Gradle, Casey A. Wood, Beerne Bettman, W. T. Montgomery, Edwin J. Gardiner, Charles H. Beard, W. Franklin Coleman, J. E. Colburn, H. M. Starkey, Lyman Ware, William A. Fisher, F. D. Stannard and Robert Tilley. In 1903 the name of the organization was changed to "The Chicago Ophthalmological Society," in accordance with the restriction in its field of work which such a change implies.

The American Academy of Ophthalmology and Oto-Laryngology, "the largest society in the world devoted to the study of diseases of the eye, ear, nose and throat," began as "The Western Ophthalmological, Otological and Laryngological Society.[95]" It was founded in 1896, as a result of letters sent out by Dr. Adolf Alt, of St. Louis, urging that such a society be created. The call, however, was issued by Dr. Hal Foster, of Kansas City. The first meeting was held at Kansas City, Mo., in April of that year, Alt being president, and with a membership of 50. To meet the growing needs of this society, the name was changed at the Indianapolis meeting, in 1903, to "The American Academy of Ophthalmology and Oto-Laryngology."

American Ophthalmic Journals.

American ophthalmic journalism began, as already stated, with the "*Archives of Ophthalmology and Otology*," a bilingual publication (German and English) founded in 1869 by Hermann Knapp and S. Moos, and published in Berlin and New York. In 1879 the journal was divided into "*The Archives of Ophthalmology*," published by

[94] For interesting details about the New York Ophthalmological Society, see an article by Alexander Duane in "*Ophthalmic Literature*," Vol. V., No. 6, June, 1915, p. 83.

[95] It was often called the "Wool" (i. e., W. O. O. L.) Society.

Knapp and Hirschberg, and "*The Archives of Otology,*" published by Knapp and Moos. In 1882 Schweigger succeeded Hirschberg as German editor, and in 1905 Hess succeeded Schweigger. In 1911, on the death of Hermann Knapp, his place as American editor was taken by his son, Dr. Arnold Knapp. Both the "*Archives*" are still bilingual.

The first exclusively American journal was "*The American Journal of Ophthalmology,*" founded at St. Louis by Dr. Adolf Alt and J. H. Chambers (publisher) in April, 1884. In 1896 the interest of Mr. Chambers was bought by Dr. Alt, who then became publisher as well as editor. It has always been, and still remains, a considerable factor in American ophthalmology.

"*The Journal of Ophthalmology, Otology and Laryngology*" (Homeopathic) was founded in 1889, in New York, by Drs. Geo. S. Norton and Charles Deady. In 1891, on the death of Dr. Norton, Dr. Deady became sole editor. "*The Homeopathic Eye, Ear, Nose and Throat Journal*" was founded in 1895 by Dr. Arthur B. Norton and others, but from 1905 till 1911 was edited by Drs. Moffat and Palmer. In 1911 it was merged into "*The Journal of Ophthalmology, Otology, and Laryngology.*" Since September, 1914, the editor has been Dr. Geo. W. Mackenzie, and the business manager Dr. J. R. McCleary, of Cincinnati. The publishers have always been Messrs. Achey and Gorrecht, Lancaster, Pennsylvania.

The first number of "*The Ophthalmic Record*" was published at Nashville, Tenn., in April, 1891, Dr. G. C. Savage being editor and publisher. A department of otology, laryngology, and rhinology, was conducted by Dr. Geo. H. Price. In May, 1896, the place of publication was changed to Chicago, the editors being Geo. E. de Schweinitz, M. D., Philadelphia; G. C. Savage, M. D., Nashville; Casey A. Wood, M. D., Chicago; John E. Weeks, M. D., New York; F. C. Hotz, M. D., Chicago; H. V. Würdemann, M. D., Milwaukee; W. E. Hopkins, M. D., San Francisco; H. Gifford, M. D., Omaha; Francis Valk, M. D., New York; A. W. Calhoun, M. D., Atlanta. In addition to these, Frank Allport, M. D., Minneapolis; A. A. Hubbell, M. D., Buffalo; F. B. Eaton, M. D., San José; J. W. Sterling, M. D., Montreal, Can.; T. Melville Black, Denver; and Wm. Dudley Hall, M. D., Buffalo, acted as collaborators, and Thomas A. Woodruff, M. D., as Editorial Secretary. For 1913 the Editorial Secretary was the present writer, who was followed by Dr. Frank Brawley, Chicago, still in charge. The journal is published today under the direct supervision of Dr. Casey A. Wood, with H. A. Fox as publisher.

"*Ophthalmology*" was founded by Harry V. Würdemann in Oct., 1904, at Milwaukee, Wis. On Oct. 8, 1908, the place of publication

was changed to Seattle, Wash. It has never merged with any other journal, and Dr. Würdemann has always been its editor-in-chief.

"*The Journal of Ophthalmology and Oto-Laryngology*" was first issued in April, 1907. Its founders were Drs. W. O. Nance and Albert H. Andrews. It has never merged with any other journal, and the place of founding and continuous publication is 32 N. State Street, Chicago.

"*Ophthalmic Literature*," as every original investigator in ophthalmology knows, occupies a unique place in the literature of our subject. It is, in fact, first and foremost a scholarly bibliography of all papers, monographs and books published on any ophthalmic subject, at any place, and in any language. It was founded in January, 1911, by Dr. Edward Jackson, at Denver, who has always been its editor, though ably assisted by Dr. W. H. Crisp. Beginning with Volume 3, January, 1913, The American Academy of Ophthalmology and Oto-Laryngology subscribed for a copy of "*Ophthalmic Literature*" for each of its Fellows who had paid his dues—an arrangement which is still continued.

At present a merger of all, or nearly all, American ophthalmic journals, is in process of formation, the leader in the movement being Dr. Edward Jackson.

Here, then, terminates the fifth division, or act, of the great ophthalmologic drama—and, from the very nature of the subject, somewhat abruptly. I should like to say much more about our own big, promising, resourceful, whole-hearted, but often inefficient country, which we love so well, and whose faults are so very clear to the most of those who will read these pages, that I have not, thus far, so much as touched upon them. All these faults—the dollar-chasing, the joy-riding, the gross neglect of unparalleled opportunity, the financial ostentation, the lack of reverence for thoughtful, brooding scholarship —I need not here dilate upon.[96] I may, however, say, in a word, that the love of gold is the grave of scientific ambition, and that the monotonous excuse that America is still very young, is beginning to look senile. In the words of the old song, "We are not so young as we used to be."

[96] But what a contrast with the scene in which the great Leonardo—musician, physicist, artist, mechanician, and sculptor—died in the arms of Francis I of France, and with that other spectacle—no less touching and uplifting (even though it occurred in "calm, impassive, and phlegmatic" Germany) in which, at the funeral of Hermann von Helmholtz, the divine Joachim expressed his heartfelt grief in soul-enrapturing harmonies, while royalty itself fell down upon its knees and bitterly wept.

Imagine an ophthalmologist, or a painter, dying in the arms of an American politician, or the governor of one of these United States attending the funeral of the greatest physiologist in America, and there weeping—barring, of course, all cases of kinship.

However, there are signs of vastly better conditions (the present *Encyclopedia of Ophthalmology* is a very striking sign) and, when our nation checks a little its nerve-assaulting pace, its reckless rush for things that do not satisfy and cannot, and begins to follow in the steps of North and of Gibson, of the Williamses, of Agnew, Noyes and Knapp (to speak of our specialty only) we believe that the scientific indebtedness of America to the older lands of Europe will be paid, paid in full, together with a bountiful usury.[97]

May it indeed be so!

A Somewhat Premature Epilogue.

What would old Father Hippocrates, the founder of scientific medicine, probably exclaim, if by the magic of a necromancer's wand, we could bring his long departed spirit back from far Elysium? What a huge astonishment would surely be his—not merely at the restoration into life, but at what he might be shown in any European or American hospital! How the ground would rock beneath his sandaled feet could he pass to a modern ophthalmic infirmary.

First of all, to be sure, we should tell him about the course of history: of the fall of ancient Greek philosophy, the rise of that of Christ (with its doctrine about the brotherhood of man) the ascension and decline of Rome, the Saracenic invasion, and all the "drums and tramplings" of innumerable conquests, and then, by the side of the noisy welter and alarm of things political and military, we should picture to his "good gray eyes" the quieter conquest of the intellect, of art, of science.

We should demonstrate (miracle upon miracle!) a host of marvels of which his teeming brain had never dreamed: anesthesia and asepsis, artificial mydriasis and myosis, the correction of innumerable difficulties by tiny bits of glass, the shadow-picture of a foreign body deep within the eye, that supreme mystagogue—the clinoscope, sclerotomy and

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[97] One of the greatest forces for good in the future field of surgery, ophthalmic as well as general, will be the American College of Surgeons, the founders of which (A. J. Ochsner, Franklin H. Martin, Charles H. Mayo, Geo. W. Crile, J. M. T. Finney, John G. Bowman, Frederick J. Cotton, Edward Martin, Rudolph Matas, Robert E. McKechnie, John B. Murphy, *et al*) should be (and will be) remembered by ophthalmologists with the deepest gratitude. Also of value for the future history of ophthalmology is the recently founded American Board for Ophthalmic Examinations, consisting of Edward Jackson, Chairman; Frank C. Todd, Secretary; William H. Wilder; Edward C. Ellett; Walter B. Lancaster; Hiram Woods; Alexander Duane; Myles Standish; and John E. Weeks.

Foremost in the work for better ophthalmic education in America are Drs. Edward Jackson and Frank C. Todd, whose services in this important matter will be more and more appreciated as the years pass.

iridectomy for glaucoma, the strabismus operation, even the *extraction* of a cataract—sans mutilation, danger, pain. Then too (as if the wonders of the age could never cease) we should show to his giddy old brain (which, by the way, he took to be a gland) by means of an electric-light ophthalmoscope, the splendor of the long-hid chambers of man's imagery, the unspeakable beauty of the visual dome—a second firmament indeed, which, no whit less than the firmament of blue, sheweth the handiwork of the Creator.

And then we should tell him, in a trembling voice of supreme reverence, "All this is thine. It is all from thee—from thee."

And then we imagine that the father of us all, the while his eyes were filled with joyful tears, as well as many fears, would thus make answer, "I? I? The old physician of Larissa? I, then, a second Prometheus! May Zeus forgive me, and recall Hephaestos! I had not thought to make of myself a rival even to the Olympians. But may mankind be blessed. Rejoice, rejoice!—Now let me go."

It is a far cry from old Larissa to modern Europe and the United States, but farther still from ancient Babylon-Assyria, the land in which, as the reader will probably remember, the science and art of ophthalmology had its very rude beginning. He may also remember (if it be not now too long ago) that, at the outset of this article, I said that the history of ophthalmology bears some resemblance to the structure of a Shakespeare drama: ophthalmology in Assyria and Egypt being the dead level of the "exposition;" Greece, and especially Hippocrates, the "exciting force," or begetter of all the development; Alexandrian, Roman, and Byzantine ophthalmology, what is called "the rising action;" the Saracenic world-upheaval, the "crisis," in which the forces of clear-headed science and the forces of intellectual chaos and anarchy were engaged in death grips, now one, now the other, uppermost, no one able even halfway to conjecture how the intolerable, age-long suspense would ultimately undergo a resolution; then on down to the Europe of the present time, the so-called "falling action;" the fifth act being America.

But what of the "catastrophe," the "goal and finely-finished summing up" of all this enormous tragedy (or comedy) which has run, in the course of its world-stage enactment, for forty-two hundred years? No fifth act should be without its "culmination" (which is perhaps the better term, for "catastrophe," to many ears, implies some sort of sorrow). What, then, should be regarded as the summarizing, all-concluding culmination of the great ophthalmologic play? The answer, in the words of the immortal Mrs. Partington, is simply this, "There ain't no sich animal." And the reason is obvious: Act V is not com-

plete. The suspense of the great ophthalmologic drama is not yet fully resolved. No man can yet declare just how this curious play will end, any more than any one can yet predict just how the history of civilization will terminate. The history of civilization is another and more embracing play, the history of ophthalmology being merely "a play within a play"—like the drama that was staged by Hamlet. There are those in abundance who truly believe that the greed and dishonesty of mankind will render a very much longer continuance of civilization an absolute impossibility. Another crisis still will come, they say, which will terminate very differently from that of the Saracenic period. Then, upon the other hand, there are those who think that war and greed and the forces of evil in general, will gradually grow weaker, while civilization and science, "with the progress of the suns," is bound to grow stronger and stronger and more beautiful. Then there are others still, who believe that the course of history is absolutely not predictable—skeptics of the Sextus Empiricus type.

Without presuming to decide, where immortal philosophers can by no means find agreement, the writer of this article will hazard a mere bald guess that greater, that *very much* greater, things indeed are still in store for ophthalmology than any that have, thus far, been disclosed by the unrolling curtains of time. In fact some all-embracing discovery or invention seems just at this particular conjuncture to be ready for revelation. It sometimes seems as if tomorrow, or the very next day at the farthest, we must suddenly be swept into an ocean of scientific light, a glorious ophthalmic jubilation, by some simple and simplifying discovery which shall make ten thousand difficulties easy in the very moment that we comprehend it. But what shall be the nature of this enormous, this all-embracing find? Perhaps some quiet, imponderable agent, on the order of the Roentgen ray, or electricity, which, filtering through the animal tissues, without provoking the very smallest injury in them, and which, as the sun dries up the frost and taketh it away, will destroy the pathogenic organisms of our bodies, and so make an end of disease—or, at least, of most of it. Perhaps this, perhaps some other measure, altogether different but quite as revolutionary. What, then, would become of innumerable operations, instruments, tinctures, pills, electuaries, eye-drops—yes, and even specialists?

Let us not dream too long, O brethren, or too deeply, lest our beatific visions turn into insufferable nightmare.—(T. H. S.)